Appendix B

Effluent Fate and Transport Modeling

APPENDIX B
EFFLUENT FATE AND TRANSPORT MODELING

A hydrodynamic model of the Potomac River was developed to simulate both river flow and the suspended solids discharge plume from the Washington Aqueduct outfalls. The primary objective of the modeling was to determine acute and chronic dilution factors as a function of effluent loading and river flow. A secondary goal was to model the fate of the released solids as they are transported downstream. The modeling used the Surfacewater Modeling System (SMS), which includes the U.S. Army COE – supported models RMA2, RMA4, and SED2D (see Section B.2). To provide the necessary data for model development and calibration, field studies were performed including:

- A bathymetry survey of this river segment to provide cross-sectional geometry for model development

- Dye-tracer and turbidity plume mapping surveys during solids discharge events at Dalecarlia (Outfall 002) and Georgetown Reservoir (Outfall 003) to provide data sets for model calibration

The results of the field surveys are presented and Section B.1 and the development of the Potomac River model is addressed in Section B.2, and modeling runs addressing the fate of the released solids and mixing zone issues are provided in Section B.3.

B.1 FIELD STUDIES

The bathymetry survey of the Potomac River area included in the model was performed on 6-7 April 2000. During the same two days, cross-sectional velocity measurements were collected along two transects. At Outfall 003 from Georgetown Reservoir, a dye-tracer plume mapping survey was performed on 2 May 2000 and a turbidity mapping survey was performed on 3 May 2000 in conjunction with a suspended solids discharge event. At Outfall 002 from Dalecarlia Basin, a dye-tracer plume mapping survey was performed on 24 May 2000 and a turbidity mapping survey was performed on 25 May 2000 in conjunction with a suspended solids discharge event from Dalecarlia Basin 3. Each of these field studies is addressed below.

B.1.1 Bathymetry Survey

A bathymetry survey of the Potomac River was conducted during 6-7 April 2000 extending for a 7.5-km distance from Memorial Bridge, upstream to Chain Bridge. During these two days, depth data were measured along a total of 46 transects, which are illustrated in Figure B.1-1. In the upstream reach approaching Chain Bridge, the higher river velocities made it difficult to perform individual transects. Therefore, one sinuous transect was performed along the centerline.

The bathymetry measurements were made using an Innerspace Model 448TDSR Depth Sounder. Positioning for the bathymetry survey was performed using an Innerspace Model 610 Mobile hydrographic differential positioning system (HDGPS). The system includes a Starlink Radiobeacon Receiver that provides real-time differential corrections. The positioning and depth data were recorded at a 1-second interval to a laptop computer used onboard the survey boat as a data logger. Water elevations during the survey were recorded using an ENDECO 1029 water level recorder. The water level recorder was deployed at a location on the opposite bank from Outfall 003 were water depths increase quickly near shore. The observed water elevations were used to adjust the depth measurements recorded during the surveys to mean low water (MLW). The tide datum was established by correlating the observed tide record from the ENDECO recorder with tide elevations reported by NOAA at Washington DC. Bathymetric cross-sections of the Potomac River are displayed in Figure B.1-2 at six representative locations along the study area. These locations are indicated in Figure B.1-1 as Transects B1 to B6.

The Surfacewater Modeling System (SMS) used for the Potomac River model has the capability to import bathymetry data and extrapolate this data to individual model nodes. To provide an improved data set for SMS extrapolation, additional cross-sectional depth transects were interpolated at a uniform 100-m spacing along the river centerline. This was accomplished by interpolating between the observed cross-sections in a direction parallel to the river centerline.

The bathymetry data used in the model was augmented with hydrographic survey data collected by the National Ocean Service (NOS). The NOS data are available from NOAA on a CD. In 1976 and 1977, NOS conducted surveys H9478 and H9488, which covered portions of the area included in the Potomac River model. In general, the bathymetry data interpolated to the 100-m transect spacing provided adequate representation of the site. The NOS data were used to augment the survey data in the vicinity of Roosevelt Island and the downstream section of the model between Roosevelt Island and Memorial Bridge.

B.1.2 Cross-Sectional Velocity Survey

On 6 and 7 April 2000, cross-sectional velocities were measured using a Marsh McBirney Model 201 flow meter. The flow meter was mounted on a rigid 4.5-m (15-ft) rod. The velocity data were measured along Transects B3 and B4, which are indicated in Figure B.1-1. Transect B3 was located approximately 400-m downstream of Outfall 003 and Transect B4 was located approximately 1,700-m downstream in a broader section of the river. The velocity surveys on both 6 and 7 April 2000 took place during an ebb tide. On 6 April 2000 the survey was performed 3.5 hrs to 5 hrs after high water, and on 7 April 2000 the survey was performed 1.5 hrs to 3 hrs after high water. Potomac River conditions during the velocity surveys are summarized in the following table.

Survey	Tide Height (m)	River Flow (cms)
6 April 2000	0.41 – 0.19	399
7 April 2000	0.74 – 0.43	372

At Transect B3, measurements were made at five stations spaced evenly across the river. At Transect B4, 6-7 stations were used. At each station, velocity readings were made at 0.6-m (2-ft) intervals down to a 3.7-m (12-ft) depth. The boat was anchored at each station. Usually the boat rode at its anchor due to the ebb current and provided a stable platform. Occasionally, the windage of the boat slackened the anchor line and the resulting movement of the boat would effect the measurements. At these times the survey crew would wait several minutes for conditions to stabilize.

The velocity data collected during 6-7 April 2000 are provided in Table B.1-1. The velocity survey was performed to provide data to use when adjusting the model's channel friction coefficients, which determine the lateral flow distribution. Since the model is vertically averaged, a vertical averaged velocity was calculated at each station and included in Table B.1-1. The velocity data will be displayed in figures as part of model calibration in Section B.2. At Transect B3, vertical average velocities were typically 10-20 cm/sec off-channel towards the left bank (stations V1 and V2). Maximum vertical average velocities of 42-59 cm/sec were in the channel at station V4.

At Transect B4, the velocity distribution was more uniform across the river and was typically 20-30 cm/sec away from the near-shore stations (stations V1 and V6). The lower 8.8 cm/sec and 11.2 cm/sec vertical average velocities at transect stations V3 and V4 on 6 April 2000 resulted from wind effects and were not used during model comparisons.

B.1.3 Plume Survey Methodology

Basin/reservoir cleanings are typically a two-step process. The overlying water is released to the river on the first day (usually a 6-14 hour period), and then the solids are hosed or pushed out on the morning of the second day (usually a 3-4 hour period). Plume mapping surveys were performed at Outfalls 002 and 003 in conjunction with suspended solids discharge events. On the day preceding the reservoir clean-out, the overlying water in the reservoir is discharged to the river to provide access. The dye-tracer studies were performed during this 6-12 hour drawdown period. The dye study can only be performed during the reservoir drawdown when relatively clean water is being discharged because the suspended sediment masks the fluorometer reading at high TSS values and provides a false positive at lower TSS levels. During the dye study, Rhodamine WT dye was injected into the discharge flow for an approximately 6-hour period. The discharge flow present on the day of the reservoir drawdown was typically several times higher than the flow used during the actual solids clean-out event. The release of dye for a several hour period allows the resulting dye distribution in the Potomac River to simulate both the build-up and subsequent dispersion of the suspended solids release, which typically lasts for approximately 3-4 hours. During the surveys, the plume mapping transects were repeated approximately every 1.5 to 2 hours. In addition, during each dye and turbidity study, at least one full mapping survey was performed after the discharge was turned off.

The transects used during the plume mapping surveys are listed in Table B.1-2 and illustrated in Figure B.1-4. Table B.1-2 includes the distance of each transect downstream from Outfalls 002 and 003. During the 2-3 May 2000 surveys at Outfall 003 (Georgetown Reservoir), Transects 7 to 20 were used. Transect 7 was the upstream background transect, and Transect 8 was located at Outfall 003. During the 24-25 May 2000 surveys at Outfall 002 (Dalecarlia Basin), Transects 1 to 20 were used, excluding Transects 8 and 9, which were closely spaced specifically for the previous Outfall 003 survey.

During the dye surveys, a 20-percent solution of rhodamine WT dye was injected into the reservoir outflow using a precision metering pump. The dye container rested on an electronic scale and the dye weight was periodically recorded and used to calculate the dye injection rate. During the dye study, effluent dye samples were collected from the reservoir outflow. At Outfall 003 (Georgetown Reservoir), the effluent sampling point was at the large concrete outfall structure near the river. At Outfall 002 (Dalecarlia Basin), the effluent sampling point was at a manhole approximately 110-m downstream of the dye injection location. The reservoir discharge flows during the dye studies were calculated from the dye injection rate and the measured effluent concentrations.

The dye plume mapping surveys were performed using a boat equipped with a Turner Designs Model 10 fluorometer set up in the flow-through mode. A 0.5-in. polyethylene sampling hose was mounted to a strut on the side of the boat at a fixed 0.3-m depth and the other end was connected to the fluorometer flow cell. An in-line pump was placed after the fluorometer to reduce the risk of air bubbles, which can cause false positive readings. A temperature probe was mounted in the flow path to provide data used to correct for the temperature dependence of dye fluorescence. The fluorometer and temperature readings were recorded at 1-second intervals with a Campbell CR10 data logger as the boat moved continuously along the survey transects.

The survey boat was also equipped with a Tremble ProXRS GPS system that also recorded continuously at a 1-second interval. Field notes were maintained on the few second offset between the system clocks on the two data loggers so that the files could be properly merged during subsequent data processing.

The fluorometer was calibrated at the end of the survey day using site water for the calibration dilutions. The site water was collected earlier in the day prior to the initiation of dye injection. The fluorometer readings and temperature data were converted to dye concentrations in parts per billion (ppb) using the relationship:

$$C(\text{ppb}) = S\,(R-R_b)\,e^{0.027\,(T-20)}$$

Where

C = dye concentration (ppb)
R = field fluorometer reading
R_b = background fluorescence
T = field temperature (°C)
S = slope from the calibration for appropriate scale

The exponential term in the above equation corrects the fluorometer reading for the temperature dependence of fluorescence to a standard 20 C value.

The turbidity plume mapping surveys were performed in a similar manner as the dye survey by continuously recording data as the boat moved along survey transects. A Coastal MacroLite with an OBS-3 turbidity sensor was mounted on a fixed strut at a 0.3-m depth. The turbidity sensor measures the back scatter of light emitted from a source contained in the probe. The turbidity values were recorded continuously at 2-second intervals to a lap-top computer that was used as a data logger. The survey boat also contained a Trimble GPS system that recorded at 1-second intervals.

An ENDECO 1029 water level recorder was deployed at a location on the opposite bank of the river from Outfall 003 for the duration of the dye and turbidity plume mapping studies.

B.1.4 Physical Conditions During the Plume Mapping Surveys

2-3 May 2000 (Outfall 003) – Georgetown Reservoir

The tide heights during the dye and turbidity plume mapping surveys on 2 and 3 May 2000 are provided in Figures B.1-5 and B.1-6. In addition to the tide curve, these figures indicate the duration of the discharge event and the times of each survey. Both the dye and turbidity studies started during an early ebb tide and the last survey was performed near or just following low slack water. On 2 May 2000, the ebb tide water elevations decreased from 1.09 m to 0.09 m, and on 3 May 2000 the ebb tide decreased from 0.93 m to -.05 m. Potomac River flows at the USGS gage at Little Falls are displayed in Figure B.1-7 for the 2-3 May 2000 period. During the 2 May 2000 dye study, river flow decreased from approximately 305 cms to 300 cms, and during the 3 May 2000 turbidity study, river flow decreased from 272 cms to 266 cms.

24-25 May 2000 (Outfall 002) – Dalecarlia Basin 3

The tide heights during the dye and turbidity plume mapping surveys on 24 and 25 May 2000 are provided in Figures B.1-8 and B.1-9. In addition to the tide curve, these figures indicate the duration of the discharge event and the times of each survey. Both the dye and turbidity studies started during an early flood tide and the last survey was performed during the following ebb tide. It should be noted that at the Potomac River flow conditions associated with these studies, the river current does not reverse direction during a flood tide, but only slows up. On 24 May 2000, the flood tide water elevations during the surveys increased from 0.53 m to 1.24 m, and on 25 May 2000 the flood tide increased from 0.32 m to 1.08 m. Potomac River flows at the USGS gage at Little Falls are displayed in Figure B.1-10 for the 24-25 May 2000 period. River flows during the 24-25 May 2000 period were significantly lower than during 2-3 May 2000. During the 24 May 2000 dye study, river flow increased from approximately 160 cms to 170 cms, and during the 25 May 2000 turbidity study, river flow increased from 190 cms to 215 cms.

B.1.5 Water Chemistry Data

River Water Chemistry Data

Surface water samples were collected as part of the turbidity plume mapping surveys on 3 May 2000 at Outfall 003, and 25 May 2000 at Outfall 002. These samples were analyzed for total suspended solids (TSS), dissolved aluminum, and total aluminum. In addition, a turbidity reading was made onboard the boat at the time of sample collection. The turbidity readings were made using a Hach model 2100 turbidity meter, which was calibrated each day using standard solutions. The water samples for total-aluminum were preserved with acid and all samples were placed on ice.

The water chemistry samples were collected along the same transects used for the turbidity mapping surveys (Figure B.1-4). However, because of the time required to collect and process each sample, only approximately every-other transect was employed. On 3 May 2000 (Outfall 003), Transects 7, 9, 11, 12, 13, 14, and 16 were used. On 25 May 2000 (Outfall 002), Transects 1, 4, 6, 9, 12, and 14 were used. A left and right sample was collected at the upstream Transects 1, 4, and 7 where the river is narrower, and a left, middle, and right sample was collected downstream where the river is wider. At each outfall, three sets of water chemistry samples were collected during the period that the four turbidity plume mapping surveys were performed. A total of 43 water samples were collected at river stations during the 3 May 2000 survey, and a total of 42 water sample were collected during the 25 May 2000 survey.

The water chemistry results from the 3 May 2000 turbidity study at Outfall 003 (Georgetown Reservoir) are provided in Table B.1-3 and the results for the 25 May 2000 study at Outfall 002 (Dalecarlia Basin 3) are provided in Table B.1-4. These tables provide concentrations for dissolved and total aluminum, TSS, and turbidity arranged by survey and transect. The tables also provide the times of the water chemistry surveys. The data from the Outfall 002 and 003 studies indicate similar relationships between the parameters, thus allowing the combined data sets to be graphically displayed. The relationship between dissolved and total aluminum is provided in Figure B.1-11. The figure indicates that dissolved Al in the surface waters sampled has a value of approximately 100-150 μg/L, which does not noticeably increase as the total Al concentrations increase from approximately 500 μg/L to 3,000 μg/L. At total Al concentrations of less than 500 μg/L, dissolved Al decreases below the 150-μg/L level.

The relationship between total Al and TSS is displayed in Figure B.1-12. The majority of the data from both the Outfall 002 and Outfall 003 studies display a linear relationship between total

Al and TSS. Figure B.1-12 indicates that as total Al increases from approximately zero to 2.5 mg/L (2,500 µg/L), TSS increases from approximately zero to 30 mg/L.

Relationship Between TSS and Turbidity

The relationship between TSS and turbidity was examined to provide a method to convert the readings from the probe used on the survey boat during the turbidity plume mapping surveys to TSS concentrations. The relationship between TSS and turbidity displayed by the 85 water chemistry samples collected during the 3 and 25 May 2000 surveys was evaluated. Figure B.1-13 indicates that a linear relationship exists with the following regression equation ($R^2 = 0.76$):

$$\text{TSS (mg/L)} = 1.541 \text{ Turbidity(NTU)} - 2.40$$

The above equation relates turbidity as measured by the Hach turbidity meter on the water chemistry sampling boat to TSS. An additional data set was examined to relate values obtained from the turbidity probe used on the plume mapping boat to the Hach meter measurements. During the turbidity surveys, 13 grab samples were collected next to the turbidity probe on the plume mapping boat. Following the survey, these samples were processed with the Hach turbidity meter. Based on these samples, the relationship between turbidity as measured by the turbidity probe and the Hach meter is provided in Figure B.1-14. Excluding 2 outliers (indicated on the figure), the data indicate a linear relationship between the two sensors. Assuming that both probes were properly calibrated to a "NTU" scale, one would expect a regression slope of 1.0 with an intercept indicating a uniform offset. Taking into account the scatter of the turbidity data, a relationship with a slope of 1.0 reasonably fits the plotted points. Following a conversation with technical staff at Coastal Leasing, the provider of the turbidity probe, a relationship with a slope of 1.0 was selected. The regression line shown in Figure B.1-14 was forced to have a slope of 1.0 and the resulting R^2 value of 0.76 was only slightly less than the 0.84 value obtained for an unconstrained regression. The relationship between the two turbidity sensors was combined with the relationship between turbidity and TSS to provide an equation to convert the survey turbidity data to TSS. An examination of the turbidity data during the two surveys indicated a slight shift in the intercept for NTU resulting in the following expressions:

$$\text{TSS (mg/L)} = 1.541 \text{ Turbidity} - 20.9 \quad \text{3 May 2000 (Outfall 003)}$$
$$\text{TSS (mg/L)} = 1.541 \text{ Turbidity} - 17.8 \quad \text{25 May 2000 (Outfall 002)}$$

In the above equations, turbidity is the value measure by the turbidity probe on the plume survey boat.

Effluent Water Chemistry Data

Effluent water chemistry samples were collected periodically from the reservoir discharge during the 2-3 May and 24-25 May 2000 studies. Similar to the river water chemistry samples, the effluent samples were analyzed for TSS and total and dissolved aluminum. The results of effluent water chemistry samples collected during the reservoir drawdown and during the suspended solids discharge on the following day are provided in Table B.1-5. At Outfall 003 (Georgetown Reservoir), TSS values were <2.5 mg/L during the drawdown phase and total aluminum concentrations ranged from 187 to 233 μg/L. During the solids discharge on the following day, TSS values ranged from 4,700 mg/L to 12,300 mg/L, with two additional values of less than 1,000 mg/L that most probably are associated with temporary lulls in the clean out. Lower TSS values could also possibly result from sampling the upper layer of a potentially stratified out flow. During the solids release on 3 May 2000, total aluminum concentrations ranged from 26 to 1,300 mg/L.

At Outfall 002 (Dalcarlia Basin), TSS concentrations were low during most of the drawdown (<5 mg/L), although TSS increased near the end as the basin elevation reached bottom. During the solids discharge on the following day, TSS concentrations ranged from 4,600 to 16,500 mg/L before dropping off to 235 mg/L at the end of the discharge event. Total aluminum concentrations during the discharge event ranged from 1,020 to 1,810 mg/L and decreased to 28.1 mg/L at the end.

B.1.6 Particle Size Distribution

The size of the particles in the effluent is an important factor in the modeling of solid's transport and deposition in the Potomac River. As discussed below, particle size distributions were determined using several methods to address the characteristics of the floc that is produced in the water treatment process.

Standard ASTM Particle Distribution

During the suspended solids discharge events, sediment samples were collected from the bottom of each reservoir. On 3 May 2000, a sediment sample was collected from Georgetown Reservoir, and on 25 May 2000, two samples were collected from Dalecarlia Basin 3. Each sample was a composite of material collected from two locations. A particle size analysis was performed on each sample and the results are provided in Table B.1-6. The two Dalecarlia samples were very similar and an average distribution is also provided in the table. Based on particle size, the Georgetown sample was 50.2 % sand, 31.6% silt, and 18.2% clay. The averaged Dalecarlia sample contained more sand and less clay and silt than the Georgetown sample. The Dalecarlia fractions were 81.3% sand, 12.4 % silt, and 6.3% clay. Since the water for both reservoirs is drawn from the same location in the Potomac River, there is no apparent reason for the particle size fractions to differ except possibly for natural seasonal variation over the period of time since the previous clean out. The Georgetown and averaged Dalecarlia data were combined to provide a composite particle size distribution that is considered to be representative of typical conditions. The composite sample was 65.7 % sand, 22.0 % silt, and 12.3 % clay (Table B.1-6).

The specific gravity of the sediment and the sediment concentrations (by weight) of the material collected from the bottom of the reservoirs are provided in the following table:

Reservoir	**Specific Gravity**	**Concentration (gm/kg)**
Georgetown	2.5	44.8
Dalecarlia	2.41	63.5

Particle Characteristics of Floc

The composite particle size distribution based on sediment samples from the Georgetown and Dalecarlia Reservoirs indicated that the material was 65.7% sand, 22.0% silt, and 12.3 % clay (Table B.1-6). However, this particle distribution does not reflect the presence of the floc resulting from the addition of alum in the treatment process. The ASTM hydrometer and sieve methodology for determining particle size uses sodium hexametaphosphate as a de-floccing agent. The resulting size distribution, therefore, reflects the underlying particles, but not the aggregated particles forming the floc. On 5 March 2001, an additional sediment sample was obtained from the bottom of a Dalecarlia basin during a clean-out event. This sample was subject to a hydrometer test without the use of a de-floccing agent. Normally for a hydrometer test, an approximately 50-gm sample of equivalent dry weight is added to a 1-liter cylinder. However, since the sediment concentrations of the gelatinous samples obtained directly from the floor of the reservoir are approximately 50 gm/kg, an equivalent 50-gm dry weight sample almost fills the cylinder, and particle settling does not occur.

In order to perform a hydrometer test, a 5-gm equivalent dry weight sample was used, which reduces the test resolution. During the hydrometer test, the settling of the floc appeared to entrain any fine particles present resulting in a fairly clear liquid above a distinct liquid/sediment interface. Starting with a mixed solution, the liquid/sediment interface was at 60 % of the cylinder height after 5 minutes, 42% of the height after 10 minutes, and 25 % of the height after 1 hour. The hydrometer responded to the rapid removal of suspended material in the upper half of the cylinder and indicated no additional change in specific gravity after approximately 15 minutes. The results of the hydrometer test are provided in Table B.1-7. The constant hydrometer readings between 15 minutes and 20 hours indicates that fine material was not present in the sample. However, the hydrometer's zero point was adjusted to take into account the reading accuracy, which resulted in 2.7 percent of the material remaining in suspension (Table B.1-7). Based upon the ASTM hydrometer test methodology, the particle settling velocity associated with the 2.7 percent of material remaining in suspension after 15 minutes is less than 0.018 cm/sec.

In a standard hydrometer test, the particle velocity is related to a particle diameter according to Stokes' law and assuming a spherical particle with a density associated with the dry sample. However, a floc is composed of a collection of particles and the floc also has a very high moisture content. The dry weight density of samples obtained from Georgetown and Dalecarlia reservoirs was approximately 2.5 gm/cm^3 (typical for soil), but the density of the original gelatinous substance was closer to 1.03 gm/cm^3 (yielding approximately 50 gm of dry weight per liter of sample). Tambo and Watanabe (1979) presented a paper on the physical characteristics of flocs including results from experimental studies with aluminum flocs. The settling velocity equation for a non-spherical floc particle was given as:

$$W\ (\text{cm/sec}) = 2882\ (rho_f - rho_w)\ D_f^2$$

Where: W = settling velocity (cm/sec)
rho_f = floc density (gm/cm^3)
rho_w = water density (gm/cm^3)
D_f = floc diameter (mm)

This paper also presented a relationship for floc density as a function of floc diameter:

$$rho_f - rho_w = 0.0005/D_f^{1.23}$$

Combining these two equations to eliminate density provides the following relationship for settling velocity as a function of floc diameter:

$$W = 0.2447\ D_f^{\ 0.77}$$

Using the above equation, floc diameters associated with the settling velocities resulting from the hydrometer test are provided in Table B.1-7. For comparison purposes, Table B.1-7 also includes particle diameters for a spherical particle. The range of settling velocities in Table B.1-7 correspond to a range of floc diameters of approximately 0.03 to 0.4 mm. A spherical sand or silt particle would require a diameter 4-10 times smaller in order to posses a similar settling velocity.

B.1.7 Plume Surveys at Outfall 003 (Georgetown Reservoir)

A dye-tracer plume mapping study was performed at Outfall 003 on 2 May 2000 while the Georgetown Reservoir was being drawn down. The following day (3 May), a turbidity plume mapping study was performed during and for several hours after a suspended solids discharge event. As discussed in Section B.1.4, both studies took place primarily during an ebb tide.

Dye Plume Mapping Surveys (2 May 2000)

On 2 May 2000, a 20-percent solution of Rhodamine WT dye was injected into the reservoir outflow starting at 0749 hours and continued until 1406 hours. Several hours into the study, the dye injection rate was increased because a higher discharge concentration would provide better resolution in the plume map. Between approximately 1240 and 1310 hours, there was a lull in dye injection because the liquid level in the dye container had fallen below the intake tube. During the period of dye injection, three effluent samples were collected at the concrete outfall structure near the river at approximately 1-hour intervals and analyzed for dye concentration. The dye injection rate as determined from the scale readings and the measured effluent concentrations are provided in Table B.1-8. The discharge flow can be calculated from the dye injection rate and the observed effluent concentrations. The calculated discharge flows are also provided in Table B.1-8. The average discharge flow based on the three samples was 3.46 cms (79 mgd).

The transects used during the dye survey were listed in Table B.1-2 and illustrated in Figure B.1-4. Outfall 003 is located at Transect 8 and Transect 7 (150-m upstream of Outfall 003) was used for background. The times of the five dye plume mapping surveys are summarized in the following table.

2 May 2000 – Outfall 003

Survey	Time (hrs)
Dye Injection	0749 - 1406
Survey 1	0820 – 0915
Survey 2	1009 – 1117
Survey 3	1134 – 1235
Survey 4	1338 – 1448
Survey 5	1509 - 1631

The dye concentration data recorded along each transect are provided in Appendix Figures A.1-1 to A.1-14 for Transects 7 to 20. The minimum, maximum, and mean dye concentrations along each transect are summarized in Table B.1-9. An examination of Table B.1-9 indicates that the leading edge of the dye plume arrived downstream at Transects 10, 13, and 16 respectively during the first three surveys. By survey 5, dye had just arrived at Transect 20 (5.05 km downstream from Outfall 003), 8.5 hours after the initiation of dye injection.

The plume buildup downstream from Outfall 003 is illustrated in the appendix figures. Background dye variation at Transect 7 (150-m upstream of the outfall) was typically within 0.02 ppb of zero (Figure A.1-1). At Transect 8 (Figure A.1-2), dye concentrations exceeded 10 ppb as the survey boat approached the discharge. During the surveys, a back eddy was observed in the shallow near shore region just downstream of Outfall 003. Higher dye concentrations were present along the offshore edge of the eddy. This is observable at Transect 9 (Figure A.1-3, 70-m downstream), which displays offshore concentrations exceeding 6 ppb during surveys 3 and 4, and with lower concentrations in the near shore region. Transects 12 and 13 (Figures A.1-6 and A.1-7), display the build up of the dye plume with increasing concentrations during surveys 1 to 4, and with a decrease in dye concentration during survey 5, approximately 1-hour after dye injection ended. Maximum dye concentrations decreased from 2.7 ppb at Transect 11 to less than 0.7 ppb at Transects 12 and 13. Transect 14 (Figure A.1-8) was far enough downstream that it did not immediately respond to the end of dye injection and dye concentrations continued to increase between surveys 4 and 5. Transects 10 to 17 (Figures A.1-4 to A.1-11) display the gradual mixing of the plume form the discharge (left) to far (right) bank.

Dye concentrations at the far bank remained at background levels upstream of Transect 16, and exceeded background at Transect 17 only during survey 5.

A plume map displaying dilution contours was constructed from the dye survey data for the 500-m region downstream from Outfall 003 (Transects 8-11). The dilution contours were based on the average dye concentrations during surveys 2 and 3, since at Transect 10, dye concentrations were already decreasing during surveys 4 and 5. The discharge dye concentration during this period was 20.7 ppb based on an average of survey values in the vicinity of the discharge. The resulting dilution contour map (Figure B.1-15) indicates that the contour for a dilution factor of 5 extended 120 m, slightly pass Transect 9, and a dilution factor of 10 extended approximately 380 m. The arc of the factor of 5-dilution contour delineates the approximate offshore extent of the eddy that was located downstream of the outfall. A dilution factor of 20 extended beyond Transect 11, which was 480-m downstream.

Turbidity Plume Mapping Surveys (3 May 2000)

On 3 May 2000, the suspended solids discharge event lasted for 3.5 hours, from approximately 1000 hours to 1330 hours. The effluent samples collected and analyzed for aluminum and TSS were previously presented in Table B.1-5. Three of the effluent samples had TSS concentrations that varied between 4,500 mg/L and 12,300 mg/L. Between 1120 and 1250 hours there appeared to be a lull in the clean-out and TSS values were temporarily less than 1,000 mg/L.

The transects used during the turbidity surveys were listed in Table B.1-2 and illustrated in Figure B.1-4. The times of the four turbidity mapping surveys are summarized in the following table.

3 May 2000 – Outfall 003

Survey	Time (hour)
Clean out	1000 - 1330
Survey 1	1018 - 1050
Survey 2	1118 - 1222
Survey 3	1301 - 1352
Survey 4	1527 - 1622

Outfall 003 is located at Transect 8 and Transect 7, 150-m upstream of Outfall 003, was used for background. During the first survey, transects were performed downstream only as far as Transect 13, because it was apparent that the survey was ahead of the turbidity plume and all readings were approaching background levels. During the remaining surveys, transects were performed through Transect 17, just upstream of Key Bridge. The turbidity data recorded along each transect are provided in Appendix Figures A.2-1 to A.1-11 at Transects 7 to 17. The relationship between turbidity and TSS developed in Section B.1.5 was used to transform the turbidity survey data into TSS. The TSS values are presented in the appendix figures by the addition of a second axis. The resulting minimum, maximum, and mean TSS concentrations along each transect are summarized in Table B.1-10.

Examination of Table B.1-10 and Figure A.2-1 indicates that mean background TSS levels at Transect 7 were typically 6-8 mg/L during the 4 surveys. At the outfall (Transect 8), a maximum value of 2,164 mg/L was measured during survey 2. The lower maximum value of 142 mg/L measured at the outfall transect during survey 3 was recorded just following the 1120-1250 hour lull in the effluent TSS concentrations. At Transects 8-10, maximum TSS concentrations were present during surveys 1-3 and values decreased by survey 4, which was started approximately 2-hours after the clean-out was completed. At Transect 9, 70-m downstream of Outfall 003, the maximum TSS was 78-86 mg/L during surveys 2 and 3, decreasing to 28 mg/L during survey 4 (Figure A.2-3). At Transect 10, 200-m downstream of Outfall 003, the maximum TSS value was 43 mg/L during survey 3, decreasing to 19 mg/L during survey 4 (Figure A.2-4).

Downstream of Transect 12 (Figures A.2-6 to A.2-11), there were no clearly evident TSS plume features. This contrasts with the previous day's dye survey when a plume was present with maximum concentrations along the near shore, extending both laterally and in a downstream direction. At Transect 16 (Figure A.2-10), slightly elevated TSS concentrations were present in the channel during survey 2. This location is farther downstream than the suspended solids plume would have been expected to reach in the 1.5 hours since the beginning of the discharge event. These slightly elevated TSS concentrations are therefore attributed to natural conditions. At Transect 17 (Figure A.2-11), the data is more irregular during survey 4 and the spikes are considered to be associated with the probe being exposed to air as the boat passes over waves.

A contoured map of TSS values is provided in Figure B.1-16 for the 450-m reach from Outfall 003 to Transect 11. The data set used for the figure is a composite of the highest turbidity values along each of these four transects during the four surveys (Figures A.2-2 to A.2-5). The turbidity values were converted to TSS using the relationship developed in Section B.1-5. The resulting TSS values were 2,000 mg/L at the outfall, decreasing to maximum values of 85 mg/L at Transect 9, 48 mg/L at Transect 10, and 43 mg/L at Transect 11. The 48-mg/L TSS value at Transect 10 corresponds to a dilution factor of at least 40:1. The high suspended loads discharged from Outfall 003 are being dissipated in the river at a higher rate than would be indicated by the dye study. In Figure B.1-16, the maximum dye concentration at Transect 10 corresponded to a dilution factor of 10:1, a factor of four smaller than that determined using the TSS plume data. The increased dilution observed in the turbidity survey may result in part from settling and stratification of TSS in the water column. The turbidity probe used for the plume mapping surveys was mounted in the upper portion of the water column. It is likely that higher TSS concentrations were present in the lower portion of the water column.

B.1.8 Plume Surveys at Outfall 002 (Dalecarlia Basin)

A dye tracer plume mapping survey was performed at Outfall 002 on 24 May 2000 while the Dalecarlia Basin was being drawn down. The following day, 25 May 2000, a turbidity plume mapping survey was performed during and for several hours after a suspended solids discharge event associated with the basin clean out. As discussed in Section B.1.4, both studies primarily took place during a flood and early ebb tide.

Dye Plume Mapping Surveys (24 May 2000)

On 24 May 2000, a 20-percent solution of Rhodamine WT dye was injected into the outflow from Dalecarlia Basin 3 starting at 0809 hours and continuing to 1415 hours. Several hours into the study the dye injection rate was increased. This was done to provide better resolution in the plume map. During the period of dye injection, 11 effluent samples were collected at a manhole several hundred meters from the injection point at approximately 30-minute intervals. The dye injection rate determined from the scale readings and the measured effluent concentrations are provided in Table B.1-11. The discharge flow can be calculated from the dye injection rate and the observed effluent concentrations. The calculated discharge flows are provided in Table B.1-11 and the average discharge flow from the 11 samples was 1.75 cms.

The discharge flow from Dalecarlia was also calculated based on the observed drawdown of Basin 3. Between 0805 hours and 1340 hours, the basin's elevation decreased 5.92 m (19.42 ft). This level change, coupled with the basin area of 5,888 m^2 yields an average discharge flow of 1.73 cms (39.6 mgd). This discharge flow is in excellent agreement with the 1.75-cms value calculated from the dye injection rate and the 1.73-cms flow value was used in subsequent analysis.

The transects used during the dye surveys were listed in Table B.1-2 and illustrated in Figure B.1-4. The times of the five dye plume mapping surveys are summarized in the following table.

24 May 2000 – Outfall 002

Survey	Time (hrs)
Dye Injection	0809 – 1415
Survey 1	0842 – 0902
Survey 2	0950 – 1029
Survey 3	1107 – 1249
Survey 4	1338 – 1509
Survey 5	1555 – 1728

Outfall 002 is located approximately 520-m upstream from Transect 1 in a relatively narrow and high velocity portion of the river. Transect 1, just below Chain Bridge was considered to be the farthest upstream location that was safe for performing lateral plume mapping surveys. During the first survey, transects were performed downstream only as far as Transect 6, because it was apparent that the survey was ahead of the dye plume and all readings were at background levels. Surveys 2 and 3 went progressively farther downstream and surveys 4 and 5 were performed to Transect 20 at Memorial Bridge. The dye concentration data recorded along each transect are provided in Appendix Figures A.3-1 to A.3-18 at Transects 1 to 20. The minimum, maximum, and mean dye concentration along each transect is summarized in Table B.1-12.

The mean transect concentrations in Table B.1-12 indicate that the downstream leading edge of the dye plume reached Transects 4, 7, and 12 respectively during the first 3 surveys. By survey 5 the dye arrived at Transect 17 (Key Bridge, 5.7 km downstream of Outfall 002), 9-hrs after the beginning of dye injection. Figure A.3-1 displays the dye build up at Transect 1 during the survey period. At this first transect, 520-m downstream of Outfall 002, the dye was already well mixed with a small concentration gradient increasing from left to right bank. The mean transect concentration increased from 0.20 - 0.24 ppb during surveys 1 and 2, to 0.44 - 0.47 ppb during surveys 3 and 4 after the dye injection rate was increased at 0953-hrs. Survey 5 started approximately 1.5 hours after the end of dye injection, and the average Transect 1 concentration had already decreased to 0.14 ppb.

At Transect 3 (Figure A.3-3), the dye plume arrived during survey 1 along the deeper right bank (higher downstream velocity), and the dye distribution built up to a more even distribution during surveys 3 and 4. At Transect 4 (Figure A.3-4), the dye was fully mixed laterally during all 5 surveys and the figure clearly shows the buildup of dye during surveys 1 to 4 and the decreased concentration during survey 5. Figure A.2-6 shows the arrival of the dye plume at Transect 6 (2,280-m downstream) during survey 2 on the right bank (main channel) and the subsequent buildup of dye on the shallower left side of the river during surveys 3 and 4. Transect 10 (Figure A.3-8) is located approximately 300-m downstream of where the river has started to widen out. Figure A.3-8 shows the arrival of the plume by survey 3 and the gradual buildup of dye concentrations along the shallow left bank area during surveys 4 and 5. The dye plume continued to mix into the left bank region at Transects 11-17 during surveys 4 and 5 (Figures A.3-11 to A.3-17). Dye was not observed at Transects 18-20 (Figures A.3-18 to A.3-20).

Between surveys 3 and 4 during the 24 May 2000 dye study at Outfall 002, the survey boat was able to travel upstream of Transect 1 and perform several mapping transects in the vicinity of the discharge. The time interval between surveys 3 and 4 was near high water and the river currents upstream of Transect 1 were less than at other times during the study. The resulting dilution contour map is presented in Figure B.1-17. During this survey (1322-1339-hrs) the discharge dye concentration was 34.2 ppb. Figure B.1-17 indicates that the 10, 30, and 40 fold dilution contours were approximately 85-m, 135-m, and 190-m downstream of Outfall 002 along the discharge (left) bank. Downstream of the outfall, there was a very sharp lateral gradient as the dye mixed from the quieter back eddy formed in the lee of the shoreline protrusion at the discharge into the high velocity and turbulent flow coming from Little Falls. Within the 200-m region included in the dilution contour map, the plume gradually mixed across the remaining width of the river.

Turbidity Plume Mapping Surveys (25 May 2000)

On 25 May 2000, the suspended solids discharge event lasted for 3.5 hours, from approximately 0830 hours to 1200 hours. The effluent samples collected and analyzed for aluminum and TSS were previously presented in Table B.1-5. Four of the five effluent samples had TSS concentrations that varied between 4,600 mg/L and 16,500 mg/L.

The transects used during the turbidity survey were listed in Table B.1-2 and illustrated in Figure B.1-4. The times of the 4 turbidity mapping surveys are summarized in the following table.

25 May 2000 – Outfall 002

Survey	Time (hour)
Clean out	0830 – 1200
Survey 1	0907 – 1006
Survey 2	1101 – 1148
Survey 3	1259 – 1345
Survey 4	1445 – 1532

During all 4 surveys, transects were performed downstream to Transect 14, while downstream of Transect 7 only every other transect was used. Although it was not possible to perform an upstream background transect, turbidity values at the downstream transects, ahead of the turbidity plume indicate background levels. The turbidity data recorded along each transect are provided in Appendix Figures A.4-1 to A.4-10 at Transects 1 to 14. The relationship between turbidity and TSS developed in Section B.1.5 was used to create a second axis on these figures to display TSS. The minimum, maximum, and mean TSS concentrations along each transect are summarized in Table B.1-13. Turbidity data were not recorded at Transects 1 and 2 during survey 1 because of an instrumentation problem.

Examination of Table B.1-13 indicates that TSS levels of 3-6 mg/L at Transects 12 and 14 during surveys 1 and 2 were most likely representative of background levels. During surveys 1 and 2, which were performed while the clean-out was in progress, the highest TSS concentration along Transects 1 to 4 was 25.1 mg/L, and transect average concentrations varied between 11.4 and 18.5 mg/L. During survey 4, several hours after the completion of the clean-out, transect average turbidities along Transects 1-4 varied between 8.5 and 9.6 mg/L. The higher TSS concentrations during surveys 1 and 2 at Transects 1 to 4 are evident in Figures A.4-1 to A.4-4. Transect 6 (Figure A.4-6) displays a built up in TSS with the mean transect value increasing from 7.7 mg/L to 12.1 mg/L during surveys 1 to 3, before decreasing to 9.0 mg/L during survey 4. At Transect 12 (Figure A.4-9), survey 4 shows an increase in TSS to 21 mg/L in mid-river, while values during the other three surveys ranged up to 13.8 mg/L, but are not noticeably distinguishable from background variation. At Transect 14 (Figure A.4-10), TSS concentrations during survey 4 were also slightly elevated in comparison to surveys 1 to 3.

Vertical TSS Data

Following each 25 May 2000 turbidity plume mapping survey, a vertical turbidity profile was performed at Transects 1, 4, 6, and 7. These vertical data are presented in Table B.1-14 after being converted to TSS. The measurements were taken mid-channel at a 1.5-m interval down to a 9-m depth, except at Transect 6, which had a shallower 4.6-m depth. At Transects 1 and 4, the vertical TSS concentrations did not vary significantly with depth, although values did vary slightly between surveys. Surveys 1 and 2, performed while the clean out was under way, had higher TSS values (10.7-16.4 mg/L) than surveys 3 and 4 (7.6-13.8 mg/L), which were performed 1.5 to 3.5 hrs after the clean-out was completed. This effect was most noticeable at the vertical station on Transect 4, which decreased from 16.9-21.2 mg/L during survey 2 to 7.9-9.0 mg/L during survey 3. At the station on Transect 7, TSS values at a 9-m depth increased during surveys 1 to 3 from 10.6 to 28.7 mg/L, then decreased back to 13.2 mg/L at survey 4, 3.5 hrs after the solids release finished.

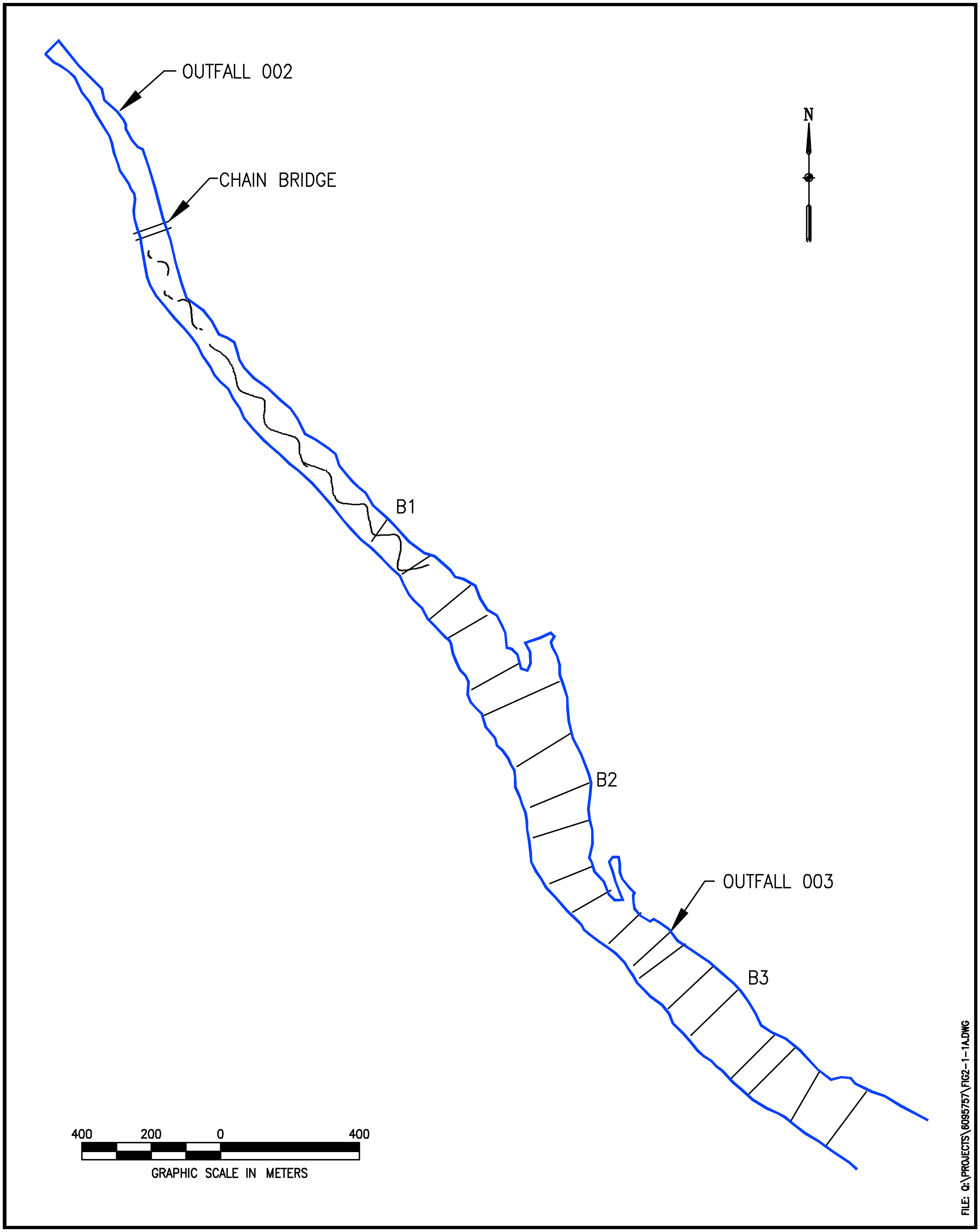


Figure B.1–1A. Transects Used During the Bathymetry Study

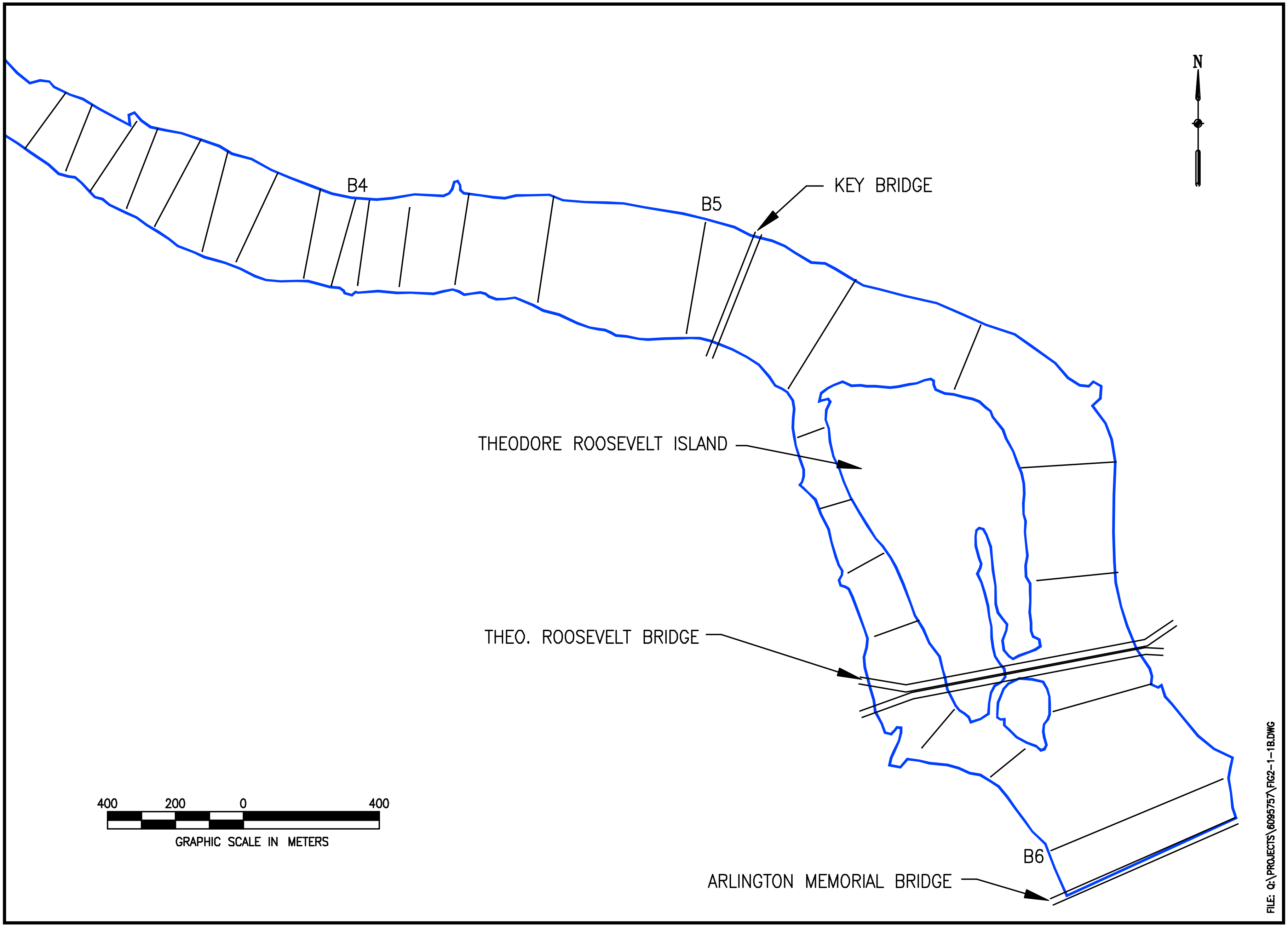


Figure B.1–1B. Transects Used During the Bathymetry Study

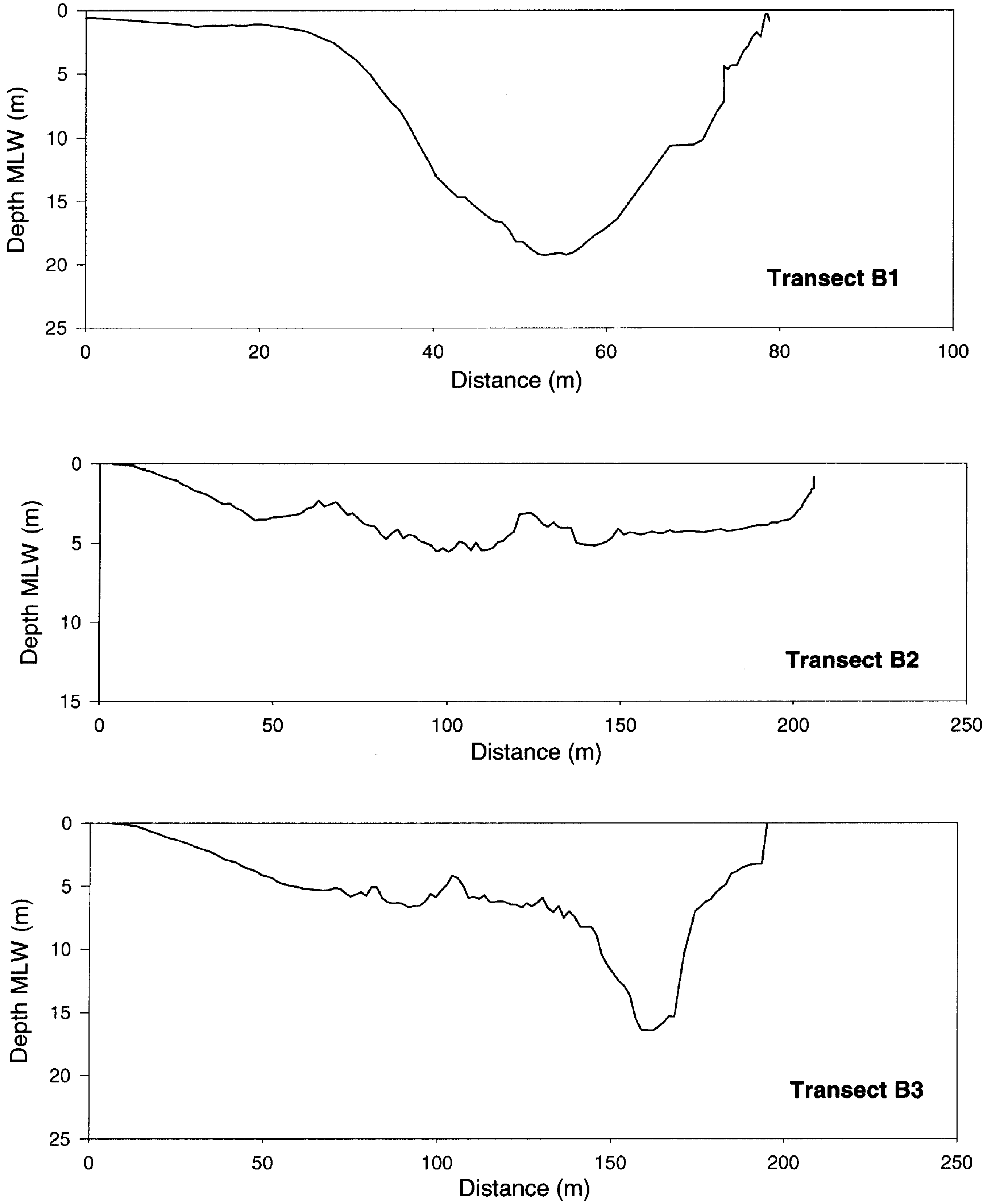


Figure B.1-2 Cross-Sectional Depth Profile at Transects B1, B2, and B3
During the 6-7 April 2000 Bathymetry Survey

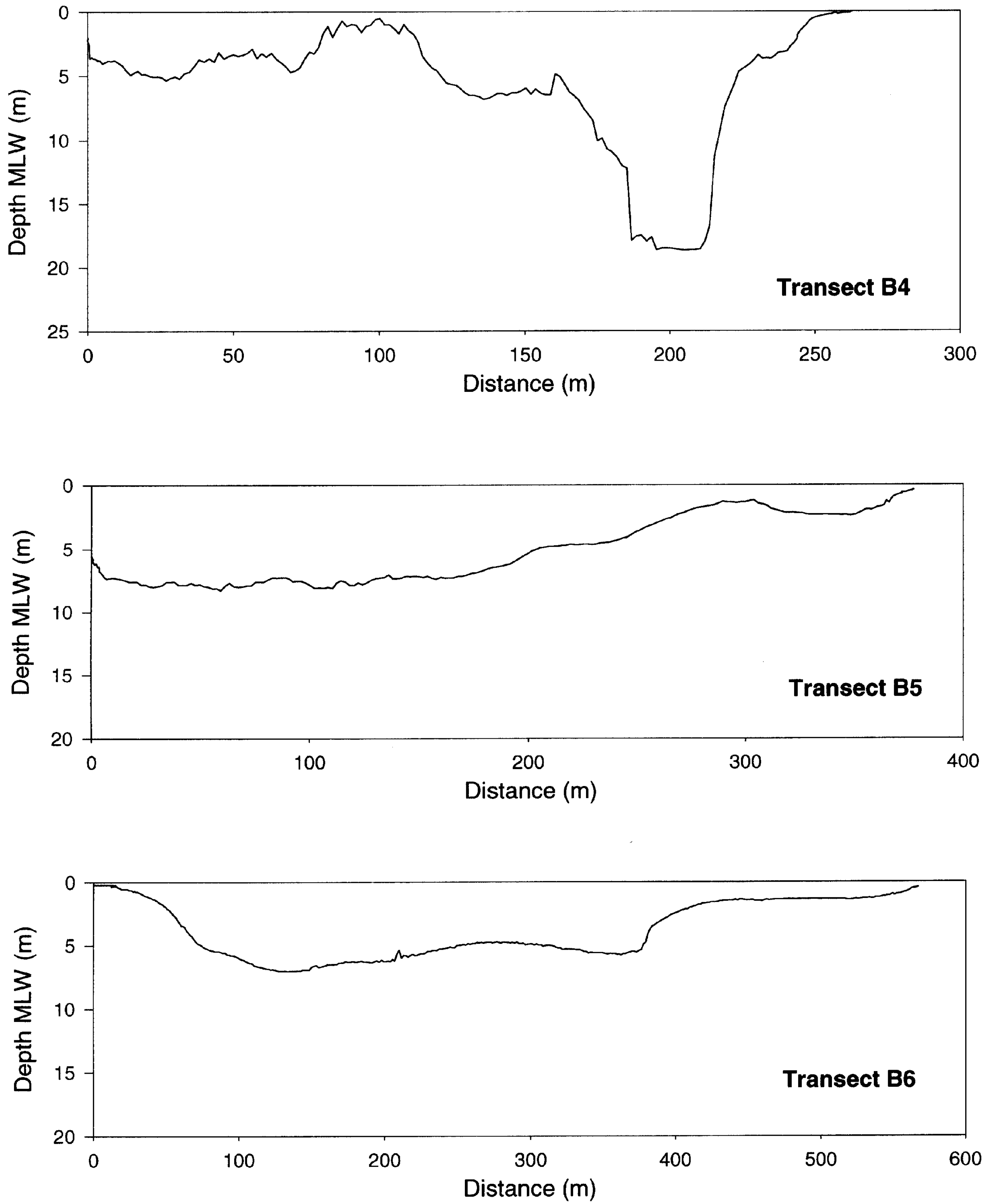


Figure B.1-3 Cross-Sectional Depth Profile at Transects B4, B5, and B6
During the 6-7 April 2000 Bathymetry Survey

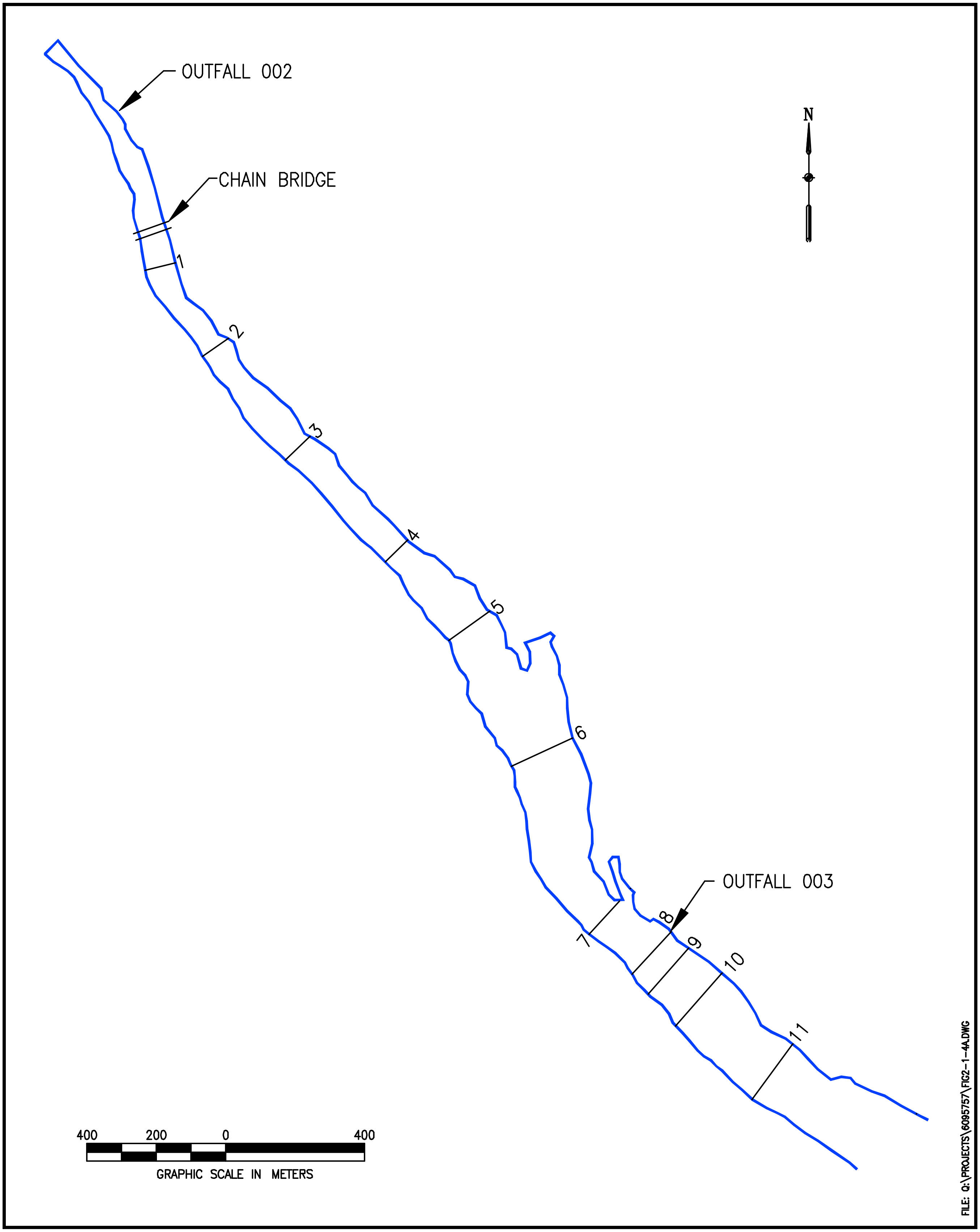


Figure B.1-4A. Transects Used During the Dye and Turbidity Plume Mapping Surveys

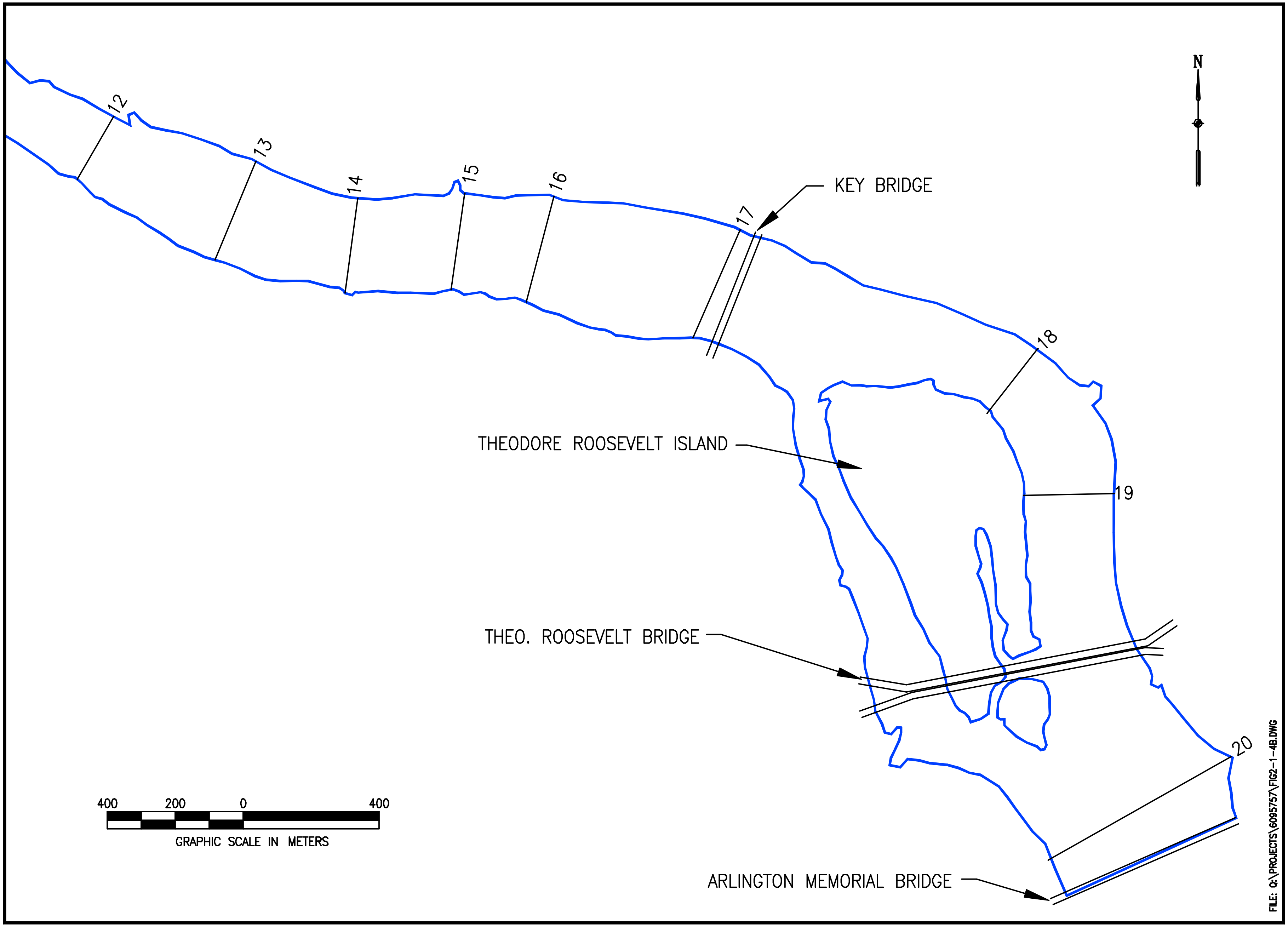


Figure B.1–4B. Transects Used During the Dye and Turbidity Plume Mapping Surveys

Figure B.1-5 Tide Height During the 2 May 2000 Dye Survey at Outfall 003, Georgetown Reservoir

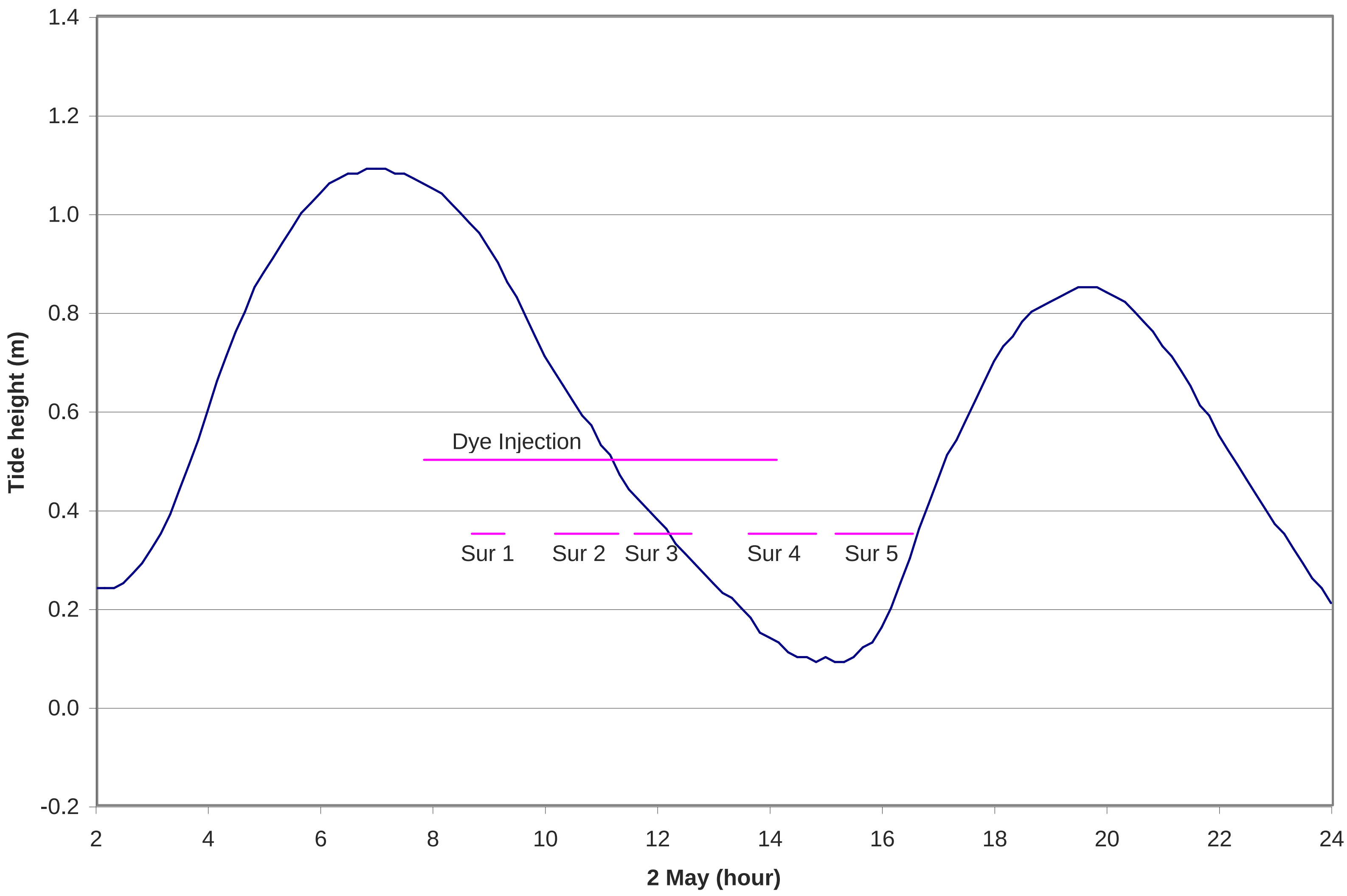


Figure B.1-6 Tide Height During the 3 May 2000 Turbidity Survey at Outfall 003, Georgetown Reservoir

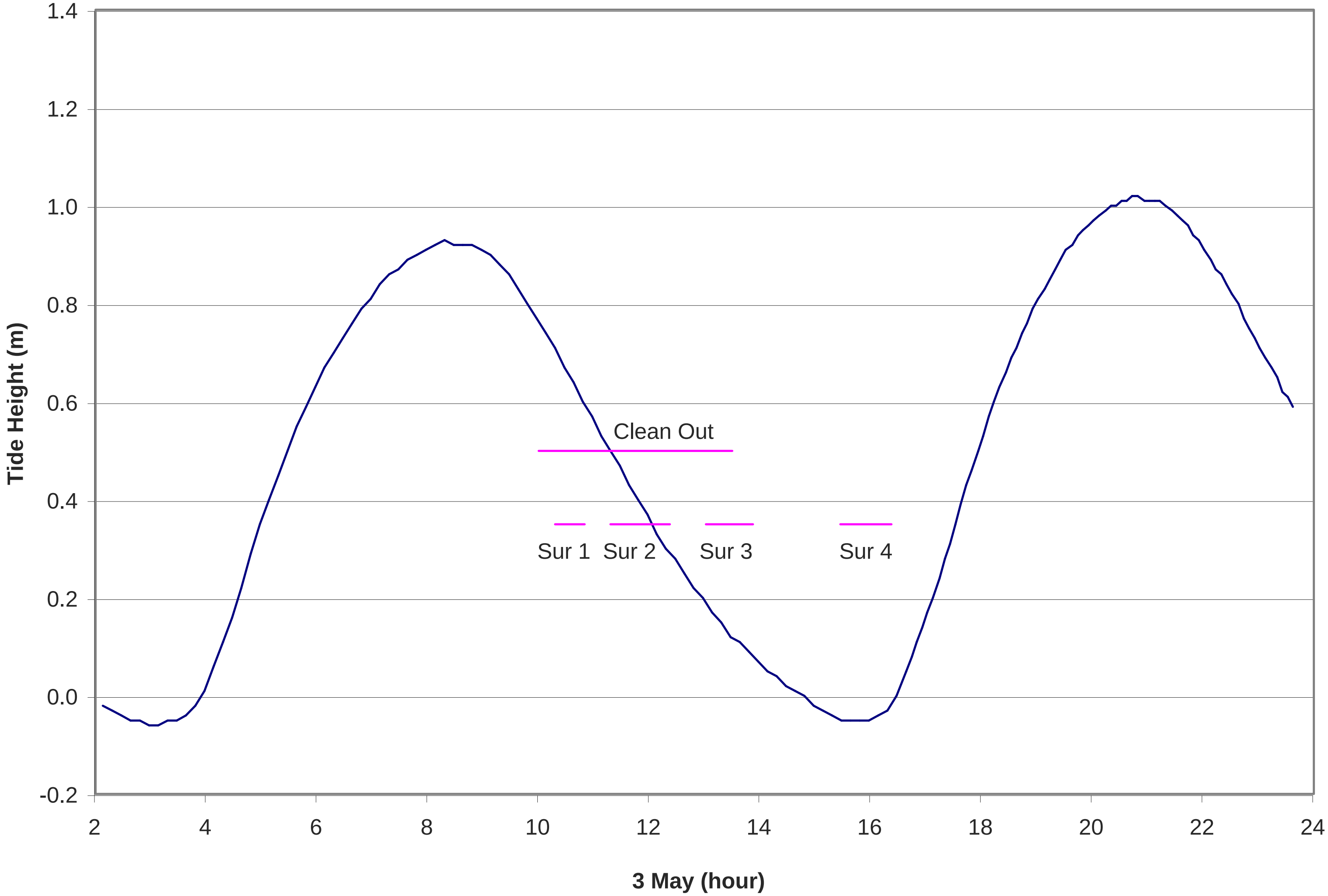


Figure B.1-7 Potomac River Flow During the 2-3 May 2000 Surveys at Outfall 003, Georgetown Reservoir

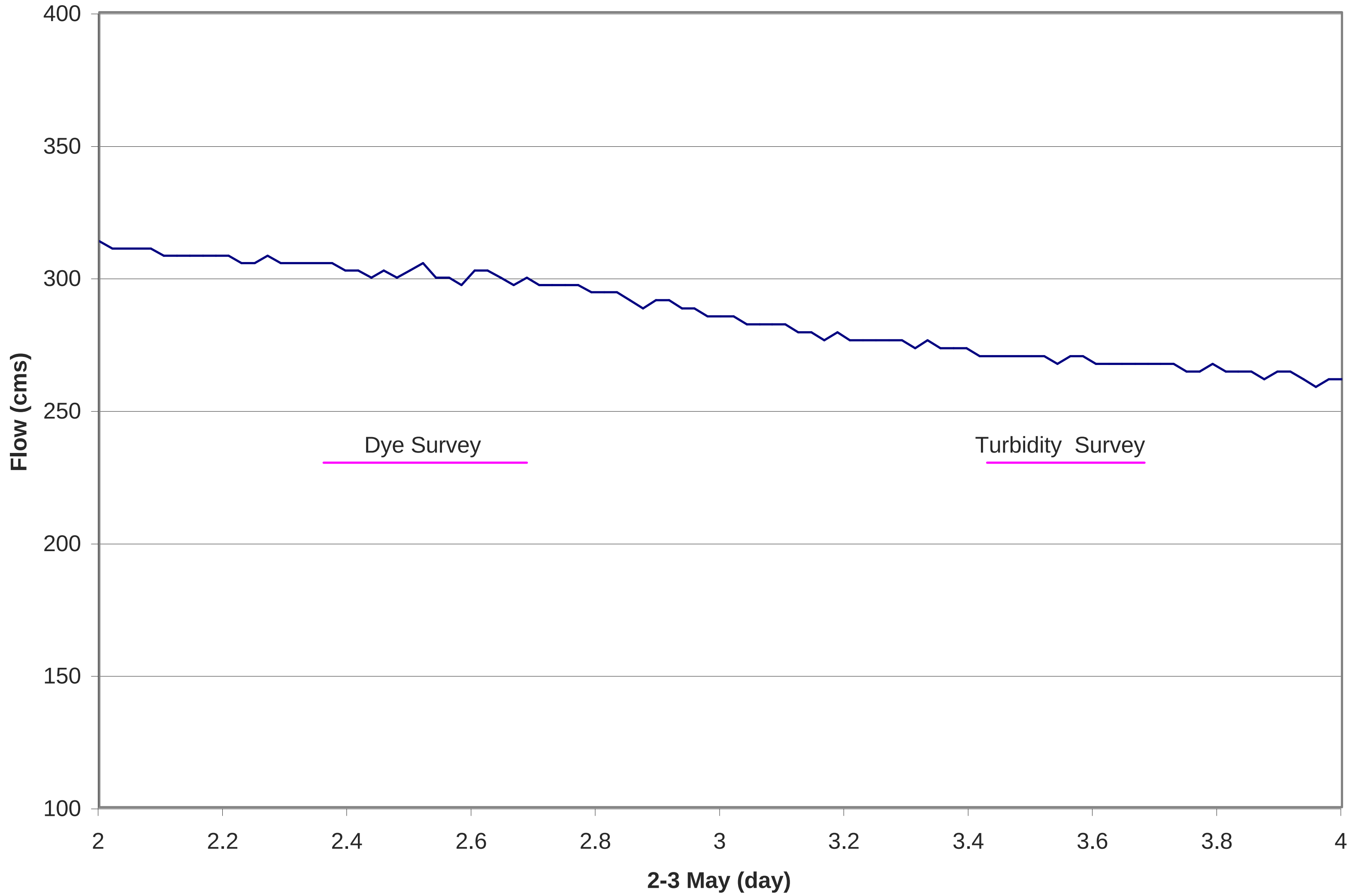


Figure B.1-8 Tide Height During the 24 May 2000 Dye Survey at Outfall 002, Dalecarlia Basin

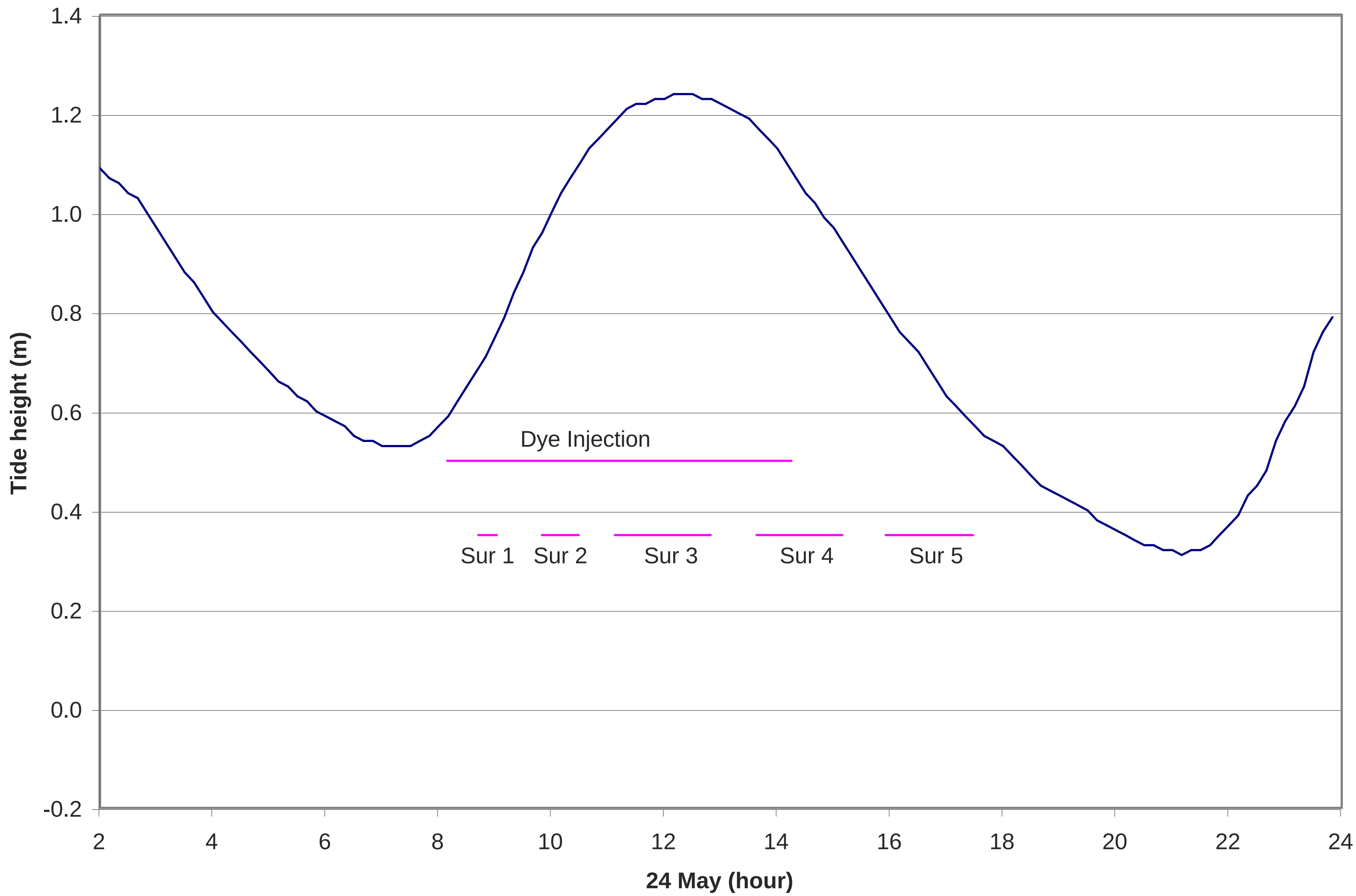


Figure B.1-9 Tide Height During the 25 May 2000 Turbidity Plume Survey at Outfall 002, Dalecarlia Basin

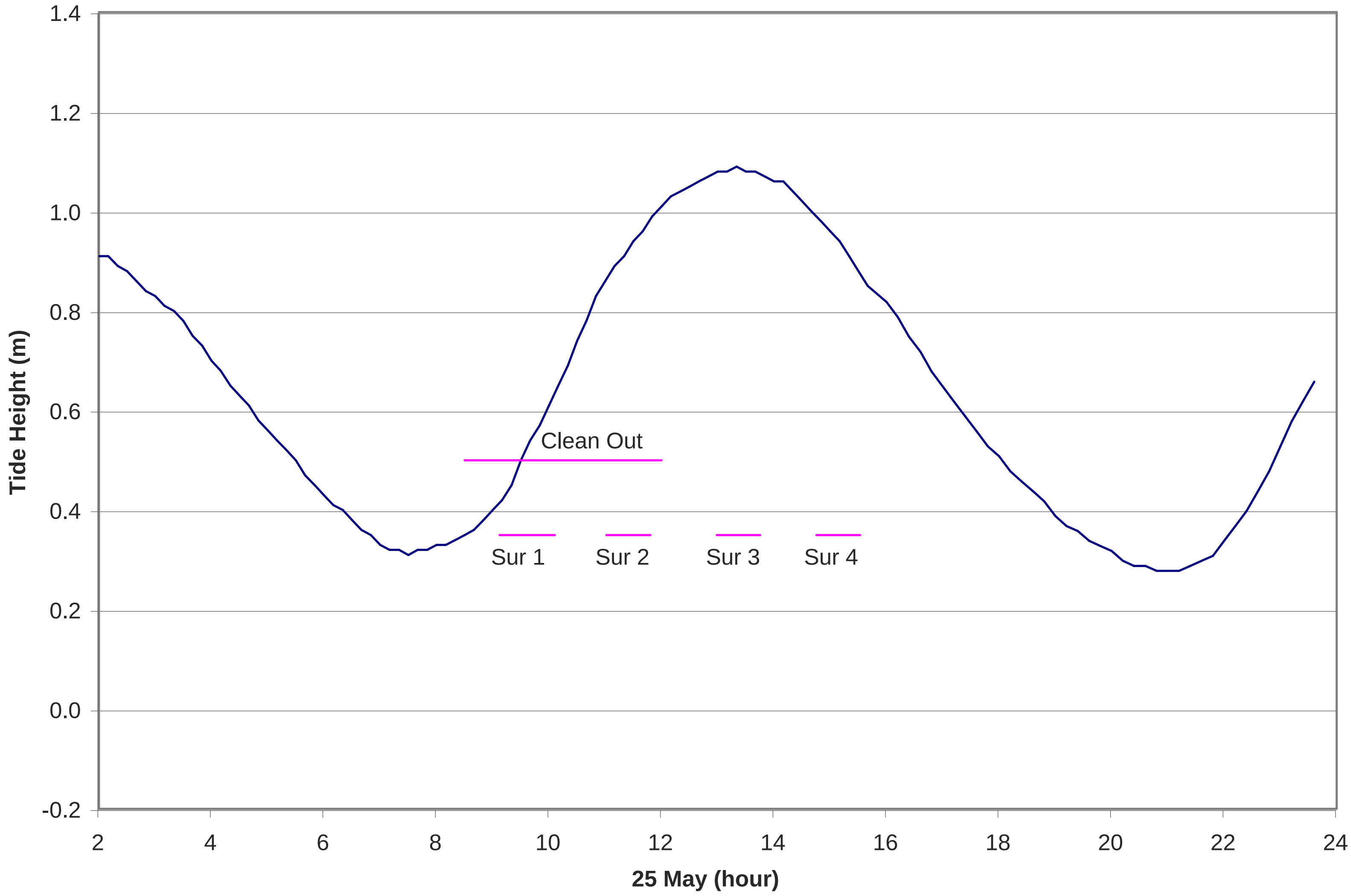


Figure B.1-10 Potomac River Flow During the 24-25 May 2000 Surveys at Outfall 002, Dalecarlia Basin

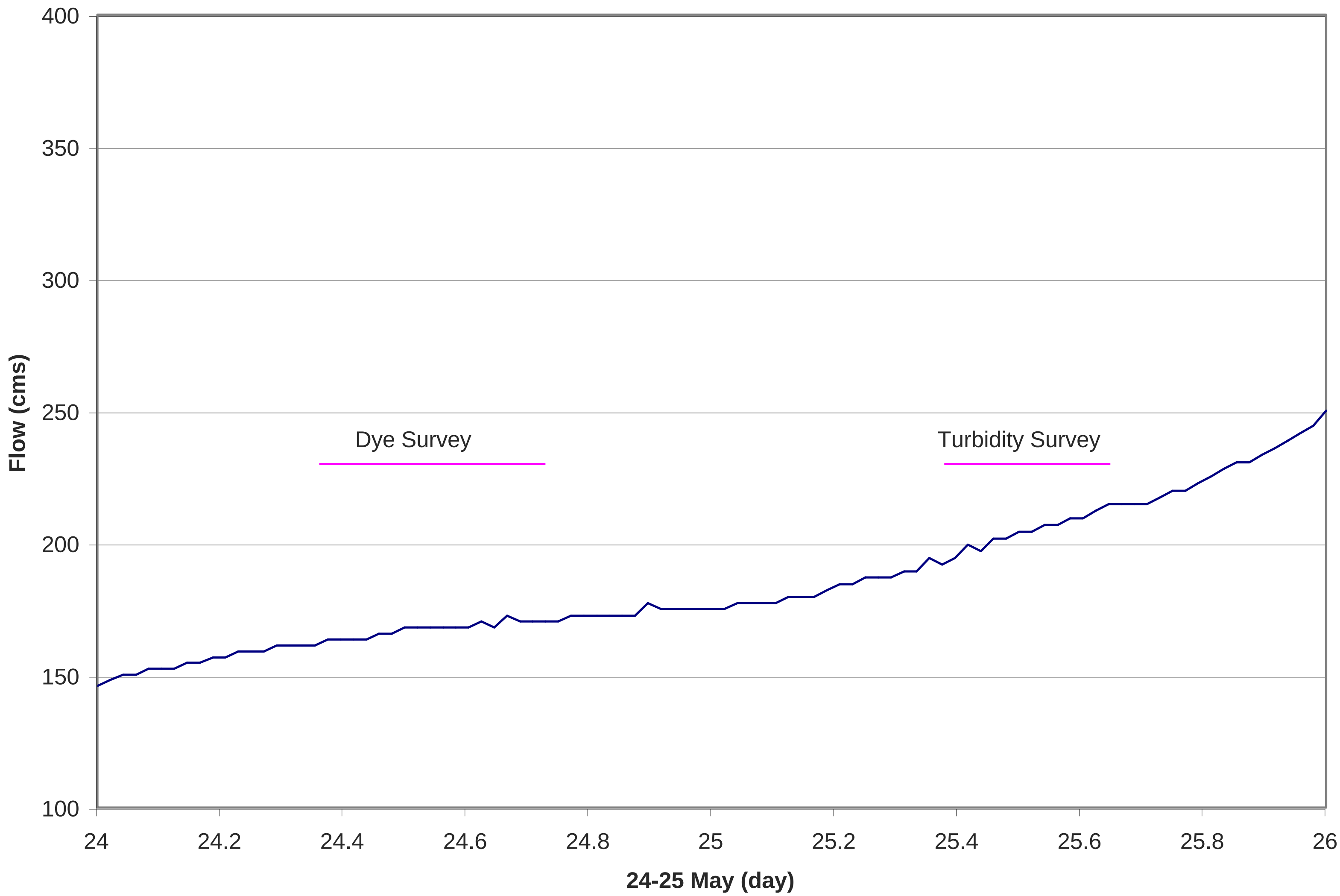


Figure B.1-11 Relationship Between Total and Dissovled Aluminum in Water Samples Collected During the Turbidity Surveys at Outfalls 002 and 003

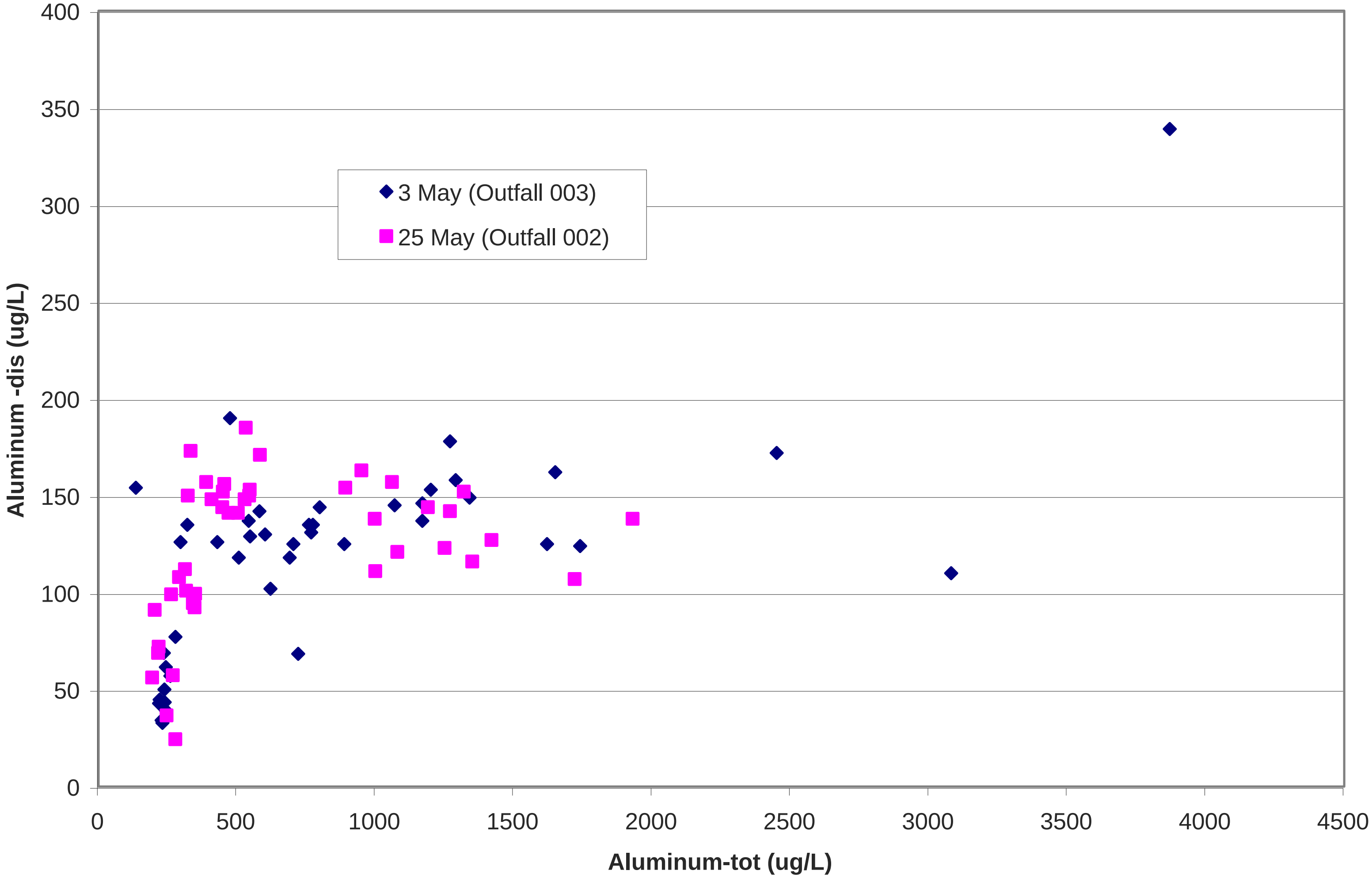


Figure B.1-12 Relationship Between Total Aluminum and TSS in Water Samples Collected During the Turbidity Surveys at Outfalls 002 and 003

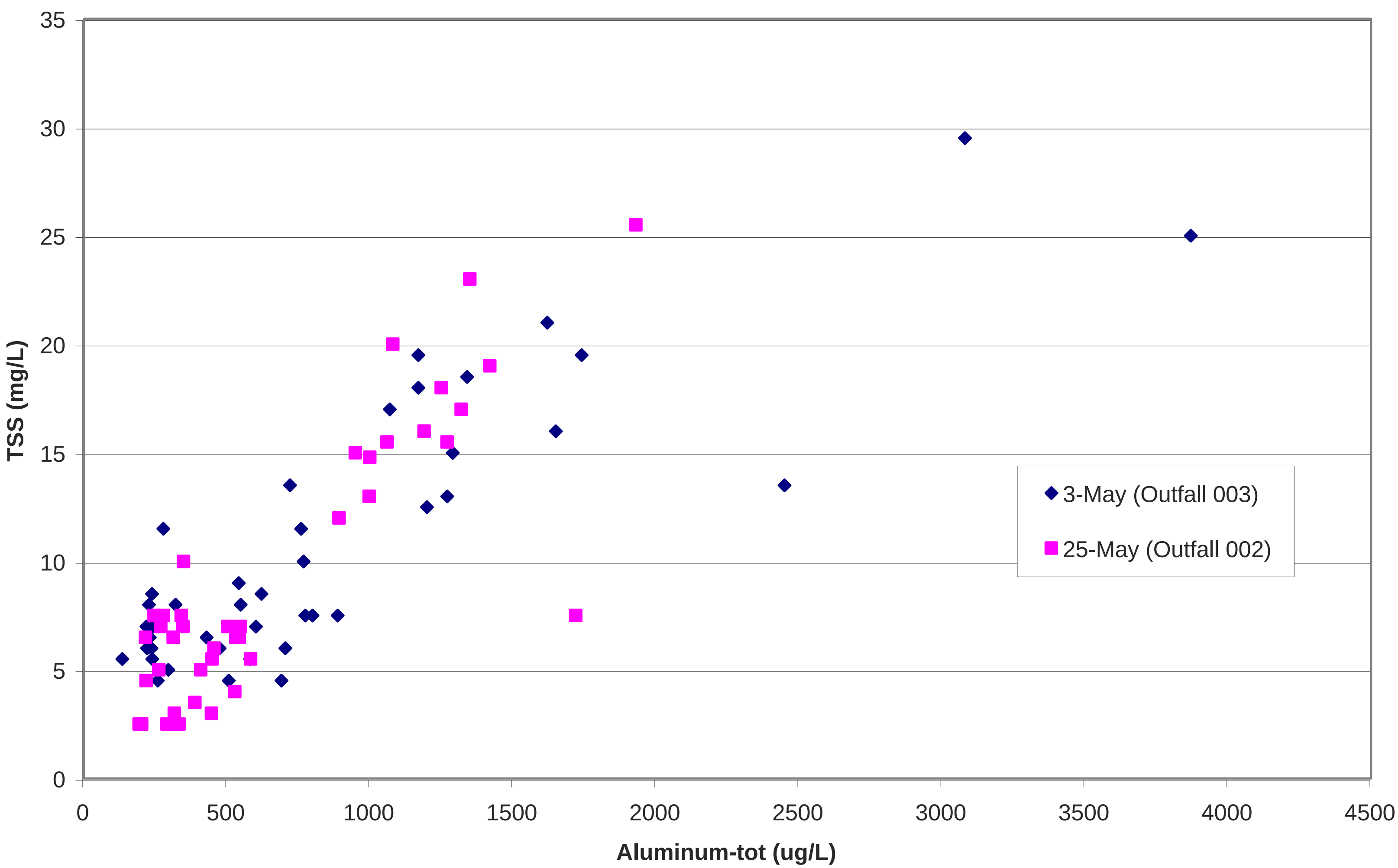
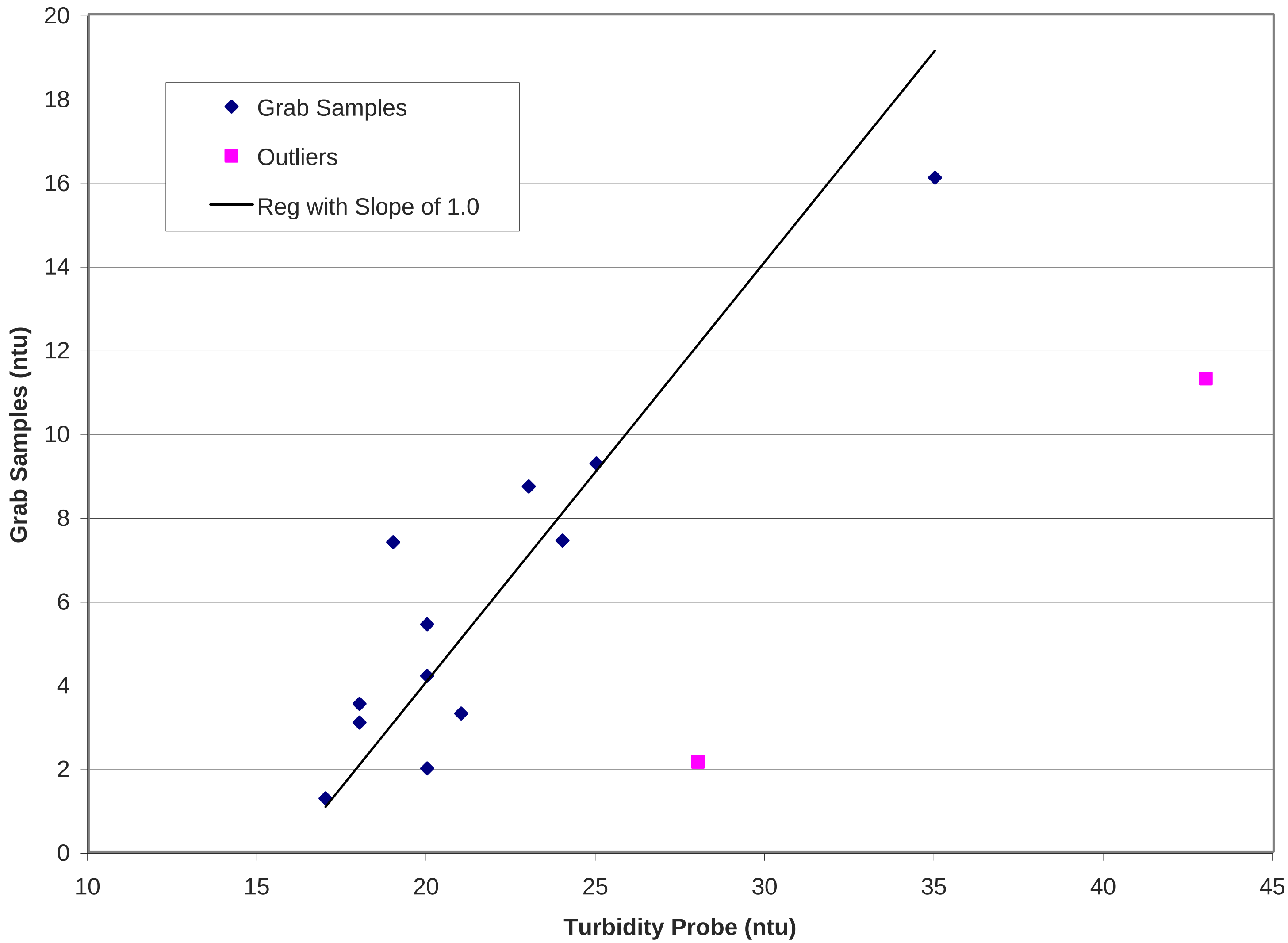


Table B.1-13 Minimum, Maximum, and Mean TSS Concentrations at Transects During the 25 May 2000 Turbidity Survey at Outfall 002, Dalecarlia Basin

Transect		TSS (mg/L) during Survey			
		1	2	3	4
1	Min		10.1	7.0	7.8
	Max		21.3	16.8	11.5
	Mean		16.2	8.9	9.5
2	Min		5.5	3.3	6.3
	Max		17.6	10.8	10.1
	Mean		13.8	8.6	8.5
3	Min	7.8	4.8	1.0	5.5
	Max	19.8	16.8	15.3	11.5
	Mean	14.5	11.4	9.6	9.1
4	Min	8.5	3.3	4.8	7.8
	Max	25.1	16.1	16.8	12.3
	Mean	18.5	11.8	11.3	9.6
5	Min	5.5	3.3	2.5	7.8
	Max	22.8	16.8	23.6	13.1
	Mean	14.5	10.7	12.2	9.8
6	Min	1.0	1.0	2.5	4.8
	Max	13.1	15.3	23.6	12.3
	Mean	7.7	8.5	12.1	9.0
7	Min	3.3	1.8	4.0	6.3
	Max	10.1	17.6	20.6	13.1
	Mean	6.8	8.2	9.8	9.5
10	Min	1.8	-1.3	-1.3	3.3
	Max	9.3	19.8	18.3	17.6
	Mean	6.2	6.3	6.9	8.5
12	Min	2.5	0.3	-0.5	2.5
	Max	13.8	10.1	11.5	21.3
	Mean	5.9	3.8	4.0	8.3
14	Min	-0.5	-0.5	-1.3	2.5
	Max	6.3	10.1	6.3	9.3
	Mean	3.1	2.5	2.5	5.9

Clean out: 0830 - 1200 hrs
Survey 1: 0907 - 1006 hrs
Survey 2: 1101 - 1148 hrs
Survey 3: 1259 - 1345 hrs
Survey 4: 1445 - 1532 hrs

Figure B.1-14 Relationship Between Turbidity Probe on Survey Boat and Grab Samples Processed with Hach Turbidity Meter



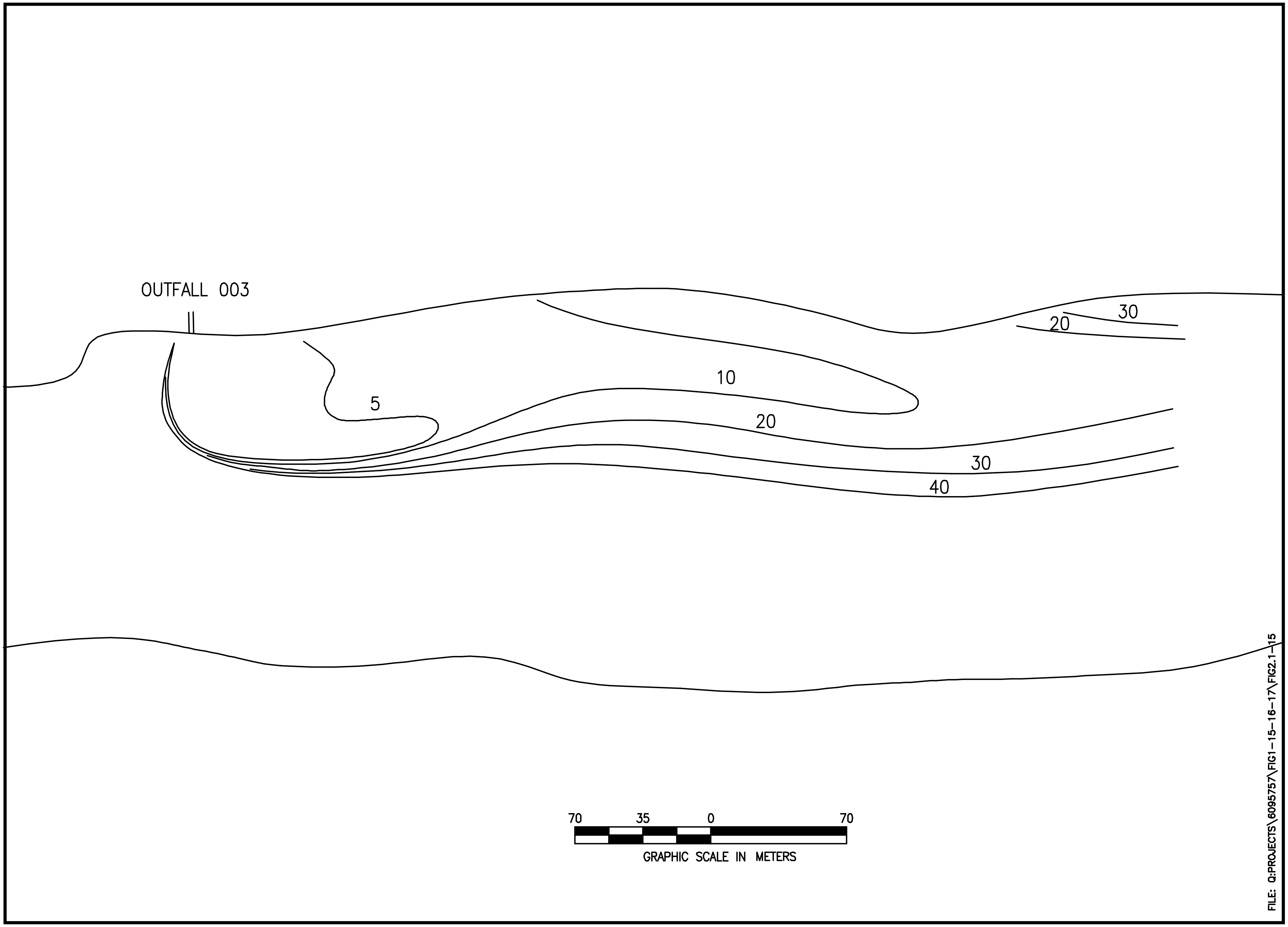


Figure B.1-15. Average Dye Dilution Contours During Surveys 2 and 3
of the Outfall 003 Plume Mapping Survey, 2 May 2000

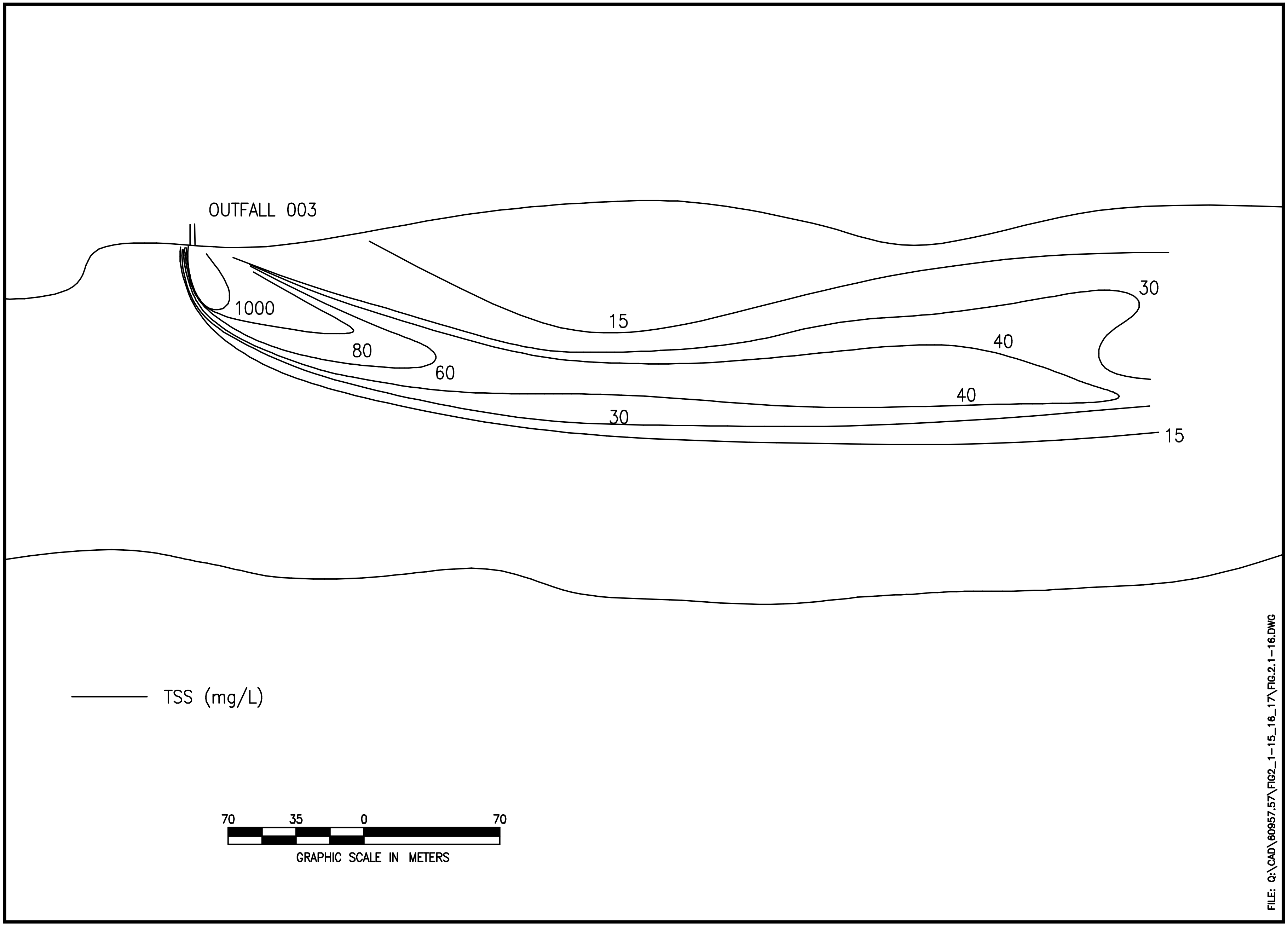


Figure B.1–16. Maximum TSS Concentrations During the Turbidity
Plume Mapping Surveys at Outfall 003, 3 May 2000

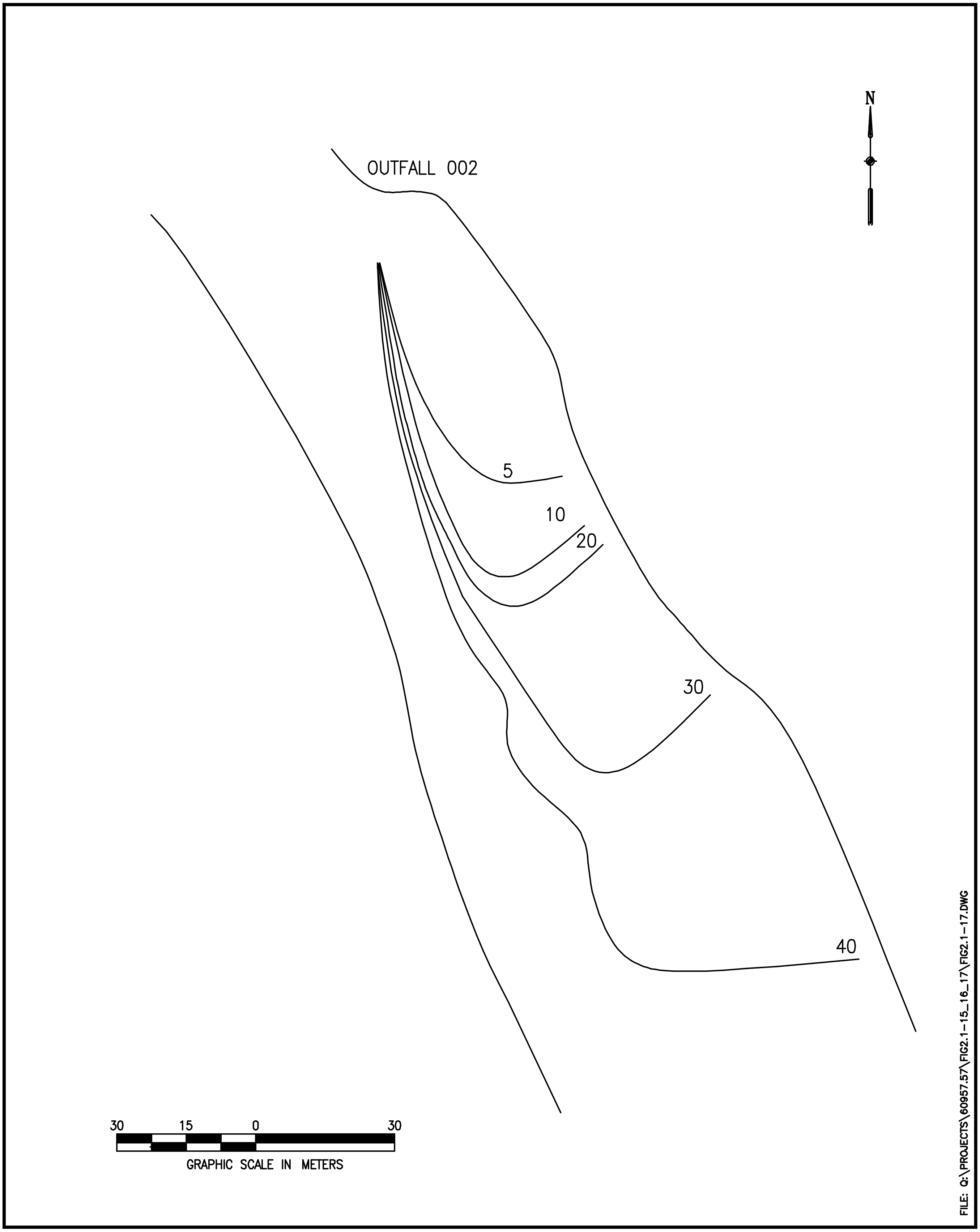


Figure B.1–17. Dye Dilution Contours During the Outfall 002 Plume Mapping Survey, 24 May 2000(1320–1340 hrs.)

Table B.1-1 Cross-Sectional Velocity Measurements at Two Potomac River Transects, 6-7 April 2000

Transect B3 - 6 April (1401-1438 hr)

Depth (m)	Velocity (cm/sec) at Station				
	V1	V2	V3	V4	V5
0.6	5.5	14.6	33.8	56.7	43.9
1.2	7.3	13.4	32.3	55.5	47.5
1.8	6.7	15.8	40.8	58.5	39.6
2.4	8.5	14.6	36.6	63.4	39.0
3.0	9.1	14.6	37.8	62.2	39.6
3.7		13.7	34.7	57.9	37.8
Mean	7.4	14.5	36.0	59.0	41.2

Transect B4 - 6 April (1456-1525 hr)

Depth (m)	Velocity (cm/sec) at Station						
	V1	V2	V3	V4	V5	V6	V7
0.6	17.1	15.2	9.1	6.1	27.4	45.7	19.8
1.2	20.4	18.3	7.9	4.6	15.2	36.6	6.1
1.8	23.8	17.1	8.5	18.3	19.8	39.0	
2.4	28.7	13.4	9.1	9.1	24.4	33.5	
3.0	25.0	6.1	13.4	16.8	21.3	29.0	
3.7	18.3		4.6	12.2	15.2	29.0	
Mean	22.2	14.0	8.8(a)	11.2(a)	20.6	35.5	13.0

a) Values not used in analysis.

Transect B3 - 7 April (1234-1316 hr)

Depth (m)	Velocity (cm/sec) at Station				
	V1	V2	V3	V4	V5
0.6	13.7	19.8	27.4	45.7	30.5
1.2	13.7	21.3	27.4	51.8	33.5
1.8	15.2	21.3	18.3	39.6	39.6
2.4	18.3	13.7	19.8	44.2	29.0
3.0		15.2	18.3	33.5	27.4
3.7		15.2	21.3	39.6	25.9
Mean	15.2	17.8	22.1	42.4	31.0

Transect B4 - 7 April (1324-1403 hr)

Depth (m)	Velocity (cm/sec) at Station					
	V1	V2	V3	V4	V5	V6
0.6	21.3	33.5	33.5	24.4	33.5	21.3
1.2	24.4	33.5	25.9	24.4	36.6	12.2
1.8	19.8	18.3	24.4	22.9	24.4	12.2
2.4	16.8		45.7	18.3	27.4	12.2
3.0	15.2		25.9	21.3	21.3	9.1
3.7	10.7		10.7	12.2	12.2	
Mean	18.0	28.4	27.7	20.6	25.9	13.4

Table B.1-2 Transects Used During the Dye and Turbidity Plume Mapping Surveys at Outfalls 002 and 003

Transect	Distance from 002 (m)	Distance from 003 (m)	Georgetown (003)		Dalecarlia (002)	
			Dye 2-May	Turbidity 3-May	Dye 24-May	Turbidity 25-May
1	520				x	x
2	790				x	x
3	1,150				x	x
4	1,560				x	x
5	1,880				x	x
6	2,280				x	x
7	2,780	-150	x	x	x	x
8	2,930	0	x	x		
9	3,000	70	x	x		
10	3,130	200	x	x	x	x
11	3,410	480	x	x	x	
12	3,830	900	x	x	x	x
13	4,320	1,390	x	x	x	
14	4,630	1,700	x	x	x	x
15	4,950	2,020	x	x	x	
16	5,190	2,260	x	x	x	
17	5,710	2,780	x	x	x	
18	6,640	3,710	x		x	
19	7,020	4,090	x		x	
20	7,980	5,050	x		x	

Table B.1-3 Water Chemistry Data Collected During the 3 May 2000 Turbidity Study at Outfall 003, Georgetown Reservoir

Aluminum-dis (ug/L)

Transect	Survey 1			Survey 2			Survey 3		
	R	M	L	R	M	L	R	M	L
7	34.2		32.8	43.4		61.6			
9	50.1	44.8	178	68.8	190	339	42.9	57.0	125
11	145	131	129	77.1	110	135	39.2	135	102
12	172	125	118	137	146	124			
13				149	137	142	126	126	118
14				162	158	144			
16				125	153	135	130	68.4	154

Aluminum-tot (ug/L)

Transect	Survey 1			Survey 2			Survey 3		
	R	M	L	R	M	L	R	M	L
7	228		231	239		243			
9	238	221	1270	236	475	3870	219	259	704
11	1070	768	548	278	3080	760	243	774	621
12	2450	1620	691	1170	1170	1740			
13				1340	542	581	429	296	507
14				1650	1290	799			
16				888	1200	321	602	721	135

TSS (mg/L)

Transect	Survey 1			Survey 2			Survey 3		
	R	M	L	R	M	L	R	M	L
7	8.0		6.5	5.5		7.0			
9	8.5	6.0	13.0	6.0	6.0	25.0	7.0	4.5	6.0
11	17.0	10.0	8.0	11.5	29.5	11.5	7.0	7.5	8.5
12	13.5	21.0	4.5	18.0	19.5	19.5			
13				18.5	9.0	5.5	6.5	5.0	4.5
14				16.0	15.0	7.5			
16				7.5	12.5	8.0	7.0	13.5	5.5

Turbidity (ntu)

Transect	Survey 1			Survey 2			Survey 3		
	R	M	L	R	M	L	R	M	L
7	6.3		8.1	7.3		6.7			
9	7.0	8.2	11.8	6.8	7.8	21.4	6.5	5.7	6.8
11	8.4	8.1	6.9	7.1	17.6	6.8	6.4	7.5	6.2
12	16.1	12.1	6.8	10.7	10.3	11.7			
13				10.9	5.8	5.6	8.2	4.5	5.2
14				11.8	10.1	6.7			
16				7.6	9.2	3.8	7.0	7.9	3.7

Note: R = right, M = middle, and L = left when facing downstream.

Survey 1: 1033 - 1119 hrs
Survey 2: 1238 - 1353 hrs
Survey 3: 1455 - 1614 hrs

Table B.1-4 Water Chemistry Data Collected During the 25 May 2000 Turbidity Study at Outfall 002, Dalecarlia Reservoir (Basin 3)

Aluminum-dis (ug/L)

	Survey 1			Survey 2			Survey 3		
Transect	R	M	L	R	M	L	R	M	L
1	111		123	142		138	36.6		24.3
4	116		127	121		152	57.4		94.6
6	138	144	112	157	154	141	107	144	148
10	99.4		101	148		152	150		171
12	56.1	68.9	92.4	153	157	156	185	163	173
14		72		91	108	99	150		141

Aluminum-tot (ug/L)

	Survey 1			Survey 2			Survey 3		
Transect	R	M	L	R	M	L	R	M	L
1	1000		1250	1270		1930	246		278
4	1350		1420	1080		1320	269		341
6	998	1190	313	1060	892	504	1720	447	528
10	349		317	409		449	544		583
12	194	216	347	547	389	455	532	950	333
14		218		203	291	263	323		470

TSS (mg/L)

	Survey 1			Survey 2			Survey 3		
Transect	R	M	L	R	M	L	R	M	L
1	14.8		18.0	15.5		25.5	7.5		7.5
4	23.0		19.0	20.0		17.0	7.0		7.5
6	13.0	16.0	6.5	15.5	12.0	7.0	7.5	3.0	4.0
10	10.0		3.0	5.0		5.5	6.5		5.5
12	2.5	6.5	7.0	7.0	3.5	6.0	6.5	15.0	2.5
14		4.5		2.5	2.5	5.0	2.5		sample?

Turbidity (ntu)

	Survey 1			Survey 2			Survey 3		
Transect	R	M	L	R	M	L	R	M	L
1	8.6		12.1	12.8		17.8	7.7		7.6
4	10.6		12.5	11.7		11.9	6.3		7.3
6	12.3	12.6	6.7	11.6	11.8	5.8	7.6	5.9	6.6
10	6.3		7.0	5.2		4.4	5.9		5.6
12	5.0	5.6	6.3	5.4	3.7	4.2	5.4	8.6	3.1
14		4.8		3.9	4.1	4.3	3.7		4.2

Note: R = right, M = middle, and L = left when facing downstream.

Survey 1: 0915 - 1034 hrs
Survey 2: 1126 - 1245 hrs
Survey 3: 1349 - 1514 hrs

Table B.1-5 Effluent Water Chemistry Data Collected During the 2-3 May 2000 Georgetown Reservoir and 24-25 May 2000 Dalecarlia Basin Studies

Georgetown Reservoir (Outfall 003)

Time (hour)	Al-dis (ug/L)	Al-tot (ug/L)	TSS (mg/L)
2 May - Drawdown			
1013	65.7	215	<2.5
1111	52.0	233	<2.5
1225	58.4	187	<2.5
1410	59.4	192	<2.5
1544	46.1	196	<2.5
3 May - Clean Out			
1005	16	1,300,000	12,300
1035	62,400(a)	761,000	4,700
1120	730	25,900	166
1205	256	32,900	
1250	1,360	256,000	958
1320	45,700(a)	661,000	4,720

Dalecarlia Basin 3 (Outfall 002)

Time (hour)	Al-dis (ug/L)	Al-tot (ug/L)	TSS (mg/L)
24 May - Drawdown			
0906	62.7	537	5
0930	61.9	271	2.5
1030	66.8	274	3.5
1305	17.7	9,080	303
1430	34.9	468,000	3,160
25 May - Clean Out			
0850	80.9		4,610
0940	<200	1,020,000	8,030
1025	107		5,550
1040		1,810,000	
1055	17.7	1,580,000	16,500
1145	108	28,100	235

a) MINTEQ, a thermodynamic equilibrium model, indicates that the dissolved fraction should be less than 1-percent of the total for these elevated total aluminum samples. These values were not used in the dissolved analysis.

Table B.1-6 Particle Size Distribution of Sediment Samples Collected in the Reservoirs during the 3 and 25 May 2000 Solids Discharge Events.

Particle Diameter (mm)	Cumulative Particle Distribution (%)				
	Georgetown	Dalecarlia			Composite(a)
		Sample-1	Sample-2	Average	
9.50	100	100	100	100	100
4.75	100	100	100	100	100
2.00	98.9	100	99.8	99.9	99.4
0.850	82.3	82.5	63.9	73.2	77.8
0.425	71.0	55.7	41.6	48.7	59.8
0.250	64.5	40.3	30.9	35.6	50.1
0.150	59.4	29.7	24.4	27.1	43.2
0.0750	54.1	21.9	19.4	20.7	37.4
0.0322	44.0	17.8	16.3	17.1	30.5
0.0210	36.8	16.2	15.8	16.0	26.4
0.0122	35.0	13.0	14.8	13.9	24.5
0.0087	33.2	12.2	13.7	13.0	23.1
0.0062	29.6	9.7	12.1	10.9	20.3
0.0032	22.4	8.1	9.5	8.8	15.6
0.0012	13.5	4.1	5.3	4.7	9.1
Sand	50.2	80.4	82.2	81.3	65.7
Silt	31.6	14.0	10.8	12.4	22.0
Clay	18.2	5.5	6.9	6.3	12.3

a) Composite was constructed using the Georgetown and the average Darcarlia sample.
Georgetown Reservoir - 3 May 2000
Dalecarlia Basin - 25 May 2000

Size Classification
Sand > 0.05 mm
Silt 0.002 < < 0.05 mm
Clay < 0.002 mm

Table B.1-7 Results of Hydrometer Test Performed on Sediment Sample Without the Use of a De-Floccing Agent

Minutes	Settling Velocity (cm/sec)	Diameter (mm)		Distribution (%)
		Spherical (a)	Floc (b)	
1	0.256	0.056	1.058	99.1
2	0.128	0.039	0.429	102.7
3	0.085	0.032	0.253	102.7
4	0.064	0.028	0.177	84.55
5	0.052	0.025	0.134	70.00
6	0.043	0.023	0.106	66.36
7	0.038	0.021	0.088	51.82
8	0.033	0.020	0.074	39.09
9	0.029	0.019	0.064	35.45
10	0.027	0.018	0.057	15.45
11	0.024	0.017	0.050	11.82
12	0.023	0.017	0.045	2.73
14	0.019	0.015	0.037	2.73
15	0.018	0.015	0.034	2.73

a) Diameter assuming a spherical particle.
b) Diameter assuming an alum floc (Tambo and Watanabe, 1979).

Table B.1-8 Dye Injection Rates, Discharge Dye Concentrations, and Calculated Discharge Flow During the 2 May 2000 Dye Study at Outfall 003 (Georgetown Reservoir)

Dye Injection Rate

Time	Dye Injection Rate (gm/min)	Calculated Concentration(a) (ppb)
0749-0924	14.7	14.2
0924-1030	17.0	16.4
1030-1240	22.0	21.2
1240-1310	dye off	
1310-1406	20.0	19.3

a) Calculated discharge concentration assuming a 3.46 cms flow.

Discharge Dye Concentration and Flow

Time (hr)	Discharge Concentration (ppb)	Calculated Discharge Flow (cms)
1013	14.8	3.83
1111	18.4	3.08
1225	21.2	3.46
	Average Flow	3.46

Table B.1-9 Minimum, Maximum, and Mean Dye Concentrations at Transects During the 2 May 2000 Dye Survey at Outfall 003, Georgetown Reservoir

Transect		Dye Concentration (ppb) during Survey				
		1	2	3	4	5
7	Min	-0.06	-0.02	-0.03	-0.03	-0.02
	Max	0.03	0.01	0.01	0.00	0.01
	Mean	0.00	-0.01	-0.01	-0.01	-0.01
8	Min	-0.04	-0.05	-0.02	-0.02	-0.01
	Max	7.80	15.71	37.71	17.52	0.58
	Mean	1.79	4.34	13.02	7.18	0.12
9	Min	-0.01	-0.02	-0.10	-0.04	-0.02
	Max	3.62	3.85	13.68	7.41	4.25
	Mean	0.99	1.52	2.86	2.70	1.92
10	Min	-0.04	-0.17	-0.02	-0.03	-0.02
	Max	0.78	3.08	3.79	1.40	1.53
	Mean	0.10	0.85	1.08	0.41	0.24
11	Min	-0.03	-0.04	-0.03	-0.02	-0.02
	Max	0.02	1.74	2.29	2.74	2.13
	Mean	0.00	0.46	0.75	1.21	0.80
12	Min	-0.02	-0.03	-0.01	-0.01	0.00
	Max	0.02	0.32	0.53	0.67	0.60
	Mean	0.00	0.12	0.21	0.34	0.26
13	Min	-0.03	-0.02	-0.02	0.00	0.01
	Max	0.02	0.11	0.40	0.58	0.65
	Mean	0.00	0.04	0.15	0.29	0.24
14	Min	-0.03	-0.04	-0.02	0.02	0.00
	Max	0.01	0.04	0.34	0.53	0.63
	Mean	-0.01	0.00	0.17	0.30	0.27
15	Min	-0.02	-0.03	-0.01	0.01	0.03
	Max	0.01	0.02	0.23	0.45	0.60
	Mean	0.00	-0.01	0.10	0.26	0.39
16	Min	-0.03	-0.04	-0.01	0.00	0.00
	Max	0.02	0.02	0.12	0.40	0.54
	Mean	0.00	-0.01	0.04	0.15	0.24
17	Min	-0.03	-0.03	-0.05	-0.01	0.02
	Max	0.02	0.02	0.03	0.27	0.41
	Mean	-0.01	-0.01	0.00	0.10	0.14
18	Min				-0.02	0.02
	Max				0.08	0.28
	Mean				0.04	0.12
19	Min					0.04
	Max					0.18
	Mean					0.08
20	Min					-0.03
	Max					0.06
	Mean					0.02

Dye injection : 0749 - 1406 hrs
Survey 1: 0820 - 0915 hrs
Survey 2: 1009 - 1117 hrs
Survey 3: 1134 - 1235 hrs
Survey 4: 1338 - 1448 hrs
Survey 5: 1509 - 1631 hrs

Table B.1-10 Minimum, Maximum, and Mean TSS Concentrations at Transects During the 3 May 2000 Turbidity Survey at Outfall 003, Georgetown Reservoir

Transect		TSS (mg/L) during Survey			
		1	2	3	4
7	Min	3.9	3.9	3.9	1.7
	Max	9.2	9.2	15.2	19.7
	Mean	5.6	6.6	8.6	13.2
8	Min	-8.1	3.9	6.2	10.0
	Max	1174.7	2164.2	142.4	16.0
	Mean	129.1	273.9	24.0	12.8
9	Min	0.9	1.7	5.4	0.9
	Max	43.1	86.0	78.4	28.0
	Mean	9.5	18.9	17.6	15.3
10	Min	0.9	2.4	1.7	7.0
	Max	48.3	38.5	43.1	19.0
	Mean	9.0	11.7	11.7	13.3
11	Min	-2.1	3.9	3.9	
	Max	30.3	43.1	29.5	
	Mean	12.3	14.8	13.0	
12	Min	0.9	0.9	7.0	2.4
	Max	38.5	28.0	28.0	33.3
	Mean	16.7	15.4	16.5	17.2
13	Min	-0.6	2.4	0.2	7.0
	Max	25.0	28.0	32.5	25.0
	Mean	7.4	8.8	10.0	13.0
14	Min		3.9	5.4	5.4
	Max		22.0	25.8	14.5
	Mean		12.1	13.2	10.4
15	Min		0.2	-0.6	3.9
	Max		40.1	28.0	22.0
	Mean		9.0	9.2	11.2
16	Min		-0.6	3.9	3.9
	Max		29.5	28.8	20.5
	Mean		7.4	10.9	10.9
17	Min		-0.6	-3.6	-8.1
	Max		8.4	16.0	40.7
	Mean		4.3	5.7	9.6

Clean out: 1000 - 1330 hrs
Survey 1: 1018 - 1050 hrs
Survey 2: 1118 - 1222 hrs
Survey 3: 1301 - 1352 hrs
Survey 4: 1527 - 1622 hrs

Table B.1-11 Dye Injection Rates, Discharge Dye Concentrations, and Calculated Discharge Flow During the 24 May 2000 Dye Study at Outfall 002 (Dalecarlia Basin)

Dye Injection Rate

Time	Dye Injection Rate (gm/min)	Calculated Concentration(a) (ppb)
0809-0953	9.4	18.1
0953-1040	15.8	30.4
1040-1255	16.9	32.5
1255-1415	17.8	34.2

a) Calculated discharge concentration assuming a 1.73-cms flow.

Discharge Dye Concentration and Flow

Time (hr)	Discharge Concentration (ppb)	Calculated Discharge Flow (cms)
906	12.60	2.49
930	16.23	1.93
1002	33.08	1.59
1030	40.67	1.29
1100	38.46	1.46
1129	46.11	1.22
1158	36.01	1.56
1230	24.64	2.29
1305	39.80	1.49
1330	25.90	2.29
1400	37.27	1.59
	Average Flow	1.75

Table B.1-12 Minimum, Maximum, and Mean Dye Concentrations at Transects During the 24 May 2000 Dye Survey at Outfall 002, Dalecarlia Basin

Transect		Dye Concentration (ppb) during Survey				
		1	2	3	4	5
1	Min	0.14	0.15	0.33	0.32	0.08
	Max	0.26	0.42	0.53	0.56	0.18
	Mean	0.20	0.24	0.44	0.47	0.14
2	Min	0.12	0.20	0.30	0.40	0.15
	Max	0.21	0.25	0.44	0.48	0.22
	Mean	0.16	0.22	0.38	0.44	0.19
3	Min	-0.01	0.03	0.18	0.33	0.18
	Max	0.13	0.23	0.39	0.38	0.32
	Mean	0.05	0.13	0.28	0.36	0.23
4	Min	0.00	0.15	0.25	0.35	0.13
	Max	0.04	0.22	0.35	0.41	0.24
	Mean	0.02	0.18	0.30	0.38	0.17
5	Min	-0.01	0.00	0.20	0.34	0.16
	Max	0.02	0.20	0.30	0.40	0.37
	Mean	0.00	0.14	0.26	0.37	0.24
6	Min	-0.02	-0.01	0.08	0.19	0.20
	Max	0.02	0.17	0.25	0.36	0.36
	Mean	0.00	0.07	0.18	0.29	0.26
7	Min		-0.01	0.01	0.20	0.23
	Max		0.05	0.18	0.32	0.34
	Mean		0.01	0.09	0.27	0.30
10	Min		-0.02	-0.01	0.00	0.03
	Max		0.02	0.19	0.31	0.38
	Mean		0.00	0.08	0.18	0.24
11	Min		-0.02	-0.01	0.01	
	Max		0.01	0.17	0.30	
	Mean		0.00	0.04	0.15	
12	Min			-0.02	0.02	0.04
	Max			0.08	0.29	0.33
	Mean			0.02	0.18	0.26
13	Min			-0.08	-0.02	
	Max			0.04	0.27	
	Mean			-0.01	0.15	
14	Min			-0.04	0.02	0.04
	Max			0.04	0.19	0.90
	Mean			0.01	0.09	0.25
15	Min			-0.02	0.00	
	Max			0.03	0.00	
	Mean			0.01	0.00	
16	Min			-0.02	-0.04	0.01
	Max			0.03	0.11	0.28
	Mean			0.01	0.04	0.18

Table B.1-13 Minimum, Maximum, and Mean TSS Concentrations at Transects During the 25 May 2000 Turbidity Survey at Outfall 002, Dalecarlia Basin

Transect		TSS (mg/L) during Survey			
		1	2	3	4
1	Min		10.1	7.0	7.8
	Max		21.3	16.8	11.5
	Mean		16.2	8.9	9.5
2	Min		5.5	3.3	6.3
	Max		17.6	10.8	10.1
	Mean		13.8	8.6	8.5
3	Min	7.8	4.8	1.0	5.5
	Max	19.8	16.8	15.3	11.5
	Mean	14.5	11.4	9.6	9.1
4	Min	8.5	3.3	4.8	7.8
	Max	25.1	16.1	16.8	12.3
	Mean	18.5	11.8	11.3	9.6
5	Min	5.5	3.3	2.5	7.8
	Max	22.8	16.8	23.6	13.1
	Mean	14.5	10.7	12.2	9.8
6	Min	1.0	1.0	2.5	4.8
	Max	13.1	15.3	23.6	12.3
	Mean	7.7	8.5	12.1	9.0
7	Min	3.3	1.8	4.0	6.3
	Max	10.1	17.6	20.6	13.1
	Mean	6.8	8.2	9.8	9.5
10	Min	1.8	-1.3	-1.3	3.3
	Max	9.3	19.8	18.3	17.6
	Mean	6.2	6.3	6.9	8.5
12	Min	2.5	0.3	-0.5	2.5
	Max	13.8	10.1	11.5	21.3
	Mean	5.9	3.8	4.0	8.3
14	Min	-0.5	-0.5	-1.3	2.5
	Max	6.3	10.1	6.3	9.3
	Mean	3.1	2.5	2.5	5.9

Clean out: 0830 - 1200 hrs
Survey 1: 0907 - 1006 hrs
Survey 2: 1101 - 1148 hrs
Survey 3: 1259 - 1345 hrs
Survey 4: 1445 - 1532 hrs

Table B.1-14 Vertical TSS Profiles Measured During the 25 May 2000
Turbidity Survey at Outfall 002, Dalecarlia Basin

Transect	Depth (m)	TSS (mg/L) during Survey			
		1	2	3	4
1	0.3	14.7	10.7	7.6	13.0
	1.5	15.6	13.2	8.6	12.6
	3.0	13.9	15.9	9.2	11.3
	4.6	14.6	14.9	8.2	10.6
	6.1	16.4	11.5	9.0	10.4
	7.6	16.4	12.2	8.4	13.9
	9.1	13.2	13.6	7.9	12.9
4	0.3	11.6	16.9	8.1	11.0
	1.5	13.0	18.6	7.9	12.7
	3.0	13.9	20.6	9.0	11.5
	4.6	13.3	21.2	8.2	10.4
	6.1	12.6	19.2	8.7	12.7
	7.6	14.6	20.9	9.0	13.3
	9.1	14.3	20.6	8.1	11.2
6	0.3	18.3	13.2	9.8	10.4
	1.5	13.6	15.3	12.4	12.4
	3.0	14.4	17.6	9.8	11.5
	4.6	18.7	16.9	13.5	13.5
7	0.3	8.2	2.8	12.6	8.7
	1.5	5.6	5.9	11.8	12.1
	3.0	7.6	10.6	11.8	11.8
	4.6	10.1	9.0	15.3	10.4
	6.1	11.3	9.6	21.8	10.2
	7.6	9.2	16.4	18.4	13.0
	9.1	10.6	16.6	28.7	13.2

Notes: Vertical profiles were performed following horizontal plume mapping.
Field turbidity values were converted to TSS.
Survey 1: 1018-1049 hrs
Survey 2: 1155-1227 hrs
Survey 3: 1352-1421 hrs
Survey 4: 1543-1617 hrs

B.2 MODEL CALIBRATION

The model used to evaluate Aqueduct discharges to the Potomac River was the Surfacewater Modeling System (SMS), developed by BOSS International and Brigham Young University. SMS is a pre- and post-processor for surface water modeling and analysis. It includes interfaces with several numerical models including the U.S. Army Corps of Engineers, Waterways Experiment Station (WES) supported models RMA2, RMA4, and SED2D.

- RMA2 is a two-dimensional depth averaged finite-element hydrodynamic numerical model. It computes water surface elevations and horizontal components for free-surface flow in two-dimensional flow fields. RMA2 was used to provide a hydrodynamic solution for the modeled portion of the Potomac River. For the Aqueduct model, time-variable river flows were applied at the upstream model boundary, and time-variable tidal elevations were applied at the downstream model boundary. The resulting output file provides a flow velocity and a water surface elevation at each model node for each solution time step.

- RMA4 is a two-dimensional finite-element water quality model. The model simulates the advection-diffusion processes and treats pollutants either as conservative or nonconservative using first order decay. RMA4 uses the hydrodynamic solution file from RMA2 as an input file along with additional information on pollutant loadings and diffusion coefficients. As part of the Aqueduct model, RMA4 was used to simulate the discharge plumes resulting from the dye studies, while treating dye as a conservative tracer. The calibration of the Aqueduct model to the observed instream dye distribution was used to establish appropriate lateral and longitudinal diffusion coefficients.

- SED2D is a two-dimensional finite-element model for vertically averaged sediment transport in open channel flow. The model simulates both deposition and erosion and treats two sediment categories: 1) “noncohesive”, which is usually referred to as sand; and 2) “cohesive”, which is referred to as clay. SED2D also uses the hydrodynamic solution file from RMA2 as an input file along with additional information including sediment loads, particle settling velocities, and shear stress for deposition and erosion. As part of the Aqueduct model, SED2D was used to model the suspended solids load during a reservoir clean-out event, and to simulate the resulting water column concentrations and the depositional patterns.

B.2.1 Model Grid

The model domain was selected to extend from a location approximately 180-m upstream of Outfall 002, downstream past Roosevelt Island to Memorial Bridge. The total length of the model along the Potomac River was 8.0 km. The finite-element nature of RMA2 allows a variable model cell size to be used. Thus, a smaller element can be used in the vicinity of the outfalls where greater resolution is desired. The dynamic nature of the discharge flow entering transverse to the river flow and the accompanying large concentration gradients makes a smaller element size in the vicinity of the outfalls necessary for improved numerical stability. During the initial model development a typical element size was approximately 100 meters long and 30-40 meters wide in the river away from the immediate vicinity of an outfall. In the final version of the model contained in this report, each of these far-field cells was subdivided into four elements with a typical element size of 50-m long and 15 to 20-m wide. A much smaller element size was used in the vicinity of Outfalls 002 and 003. The model places nodes at the corner of each element and also mid-way along each side. The Aqueduct model contains a total of 2021 elements and 6281 nodes. For each model time step, the model solution files contains x and y velocity components, water surface elevations, and concentrations at each node. In general, the model was approximately 6 elements wide upstream in the vicinity of Outfall 002, increasing to 12 elements wide by Outfall 003. Between Outfall 003 and Roosevelt Island, the model maintained 12 elements across the river, although the element width varied with the river width resulting in curve-linear coordinates. The original 100-m elements were maintained below Roosevelt Island approaching the downstream tidal boundary.

Outfalls 002 and 003 were modeled as an inset box on the shoreline. The discharge at Outfall 003 was very turbulent with high velocities that would be unstable in a numerical model. The width and depth of the element representing Outfall 003 was set at the smallest value for which numerical stability could be maintained in the model. At Outfall 002, the actual discharge is sub-surface and a surface boil was observed during the dye study located in the lower velocity region in the lee of the shoreline protrusion at the outfall. Because of this orientation, the size of the inset box on the shoreline used to represent Outfall 002 was not considered to be important for representation of downstream plume characteristics.

The finer model grid in the vicinity of Outfalls 002 and 003 are displayed in Figure B.2-1. The smaller elements at Outfall 002 are approximately 5x5 m and the smaller elements at Outfall 003 are 5x7 m. The model grid used in the Potomac River beyond the vicinity of the outfalls is displayed in Figure B.2-2, which extends from below Outfall 003 to the downstream end of the model at Arlington Memorial Bridge.

B.2.2 RMA2 Model Development

Model Boundaries

The RMA2 model was set-up using real-time data at the upstream and downstream boundaries. At the upstream boundary, the 15-minute USGS flow data was obtained at the Little Falls gage on days that field surveys were performed (Figures B.1-7 and B.1-10). At the downstream boundary the 5-min tide data obtained from the water level recorder deployed during each field survey was used. The correction of this data to a MLW datum was discussed in Section B.1.1, and the tide curves on the days of the dye and turbidity plume mapping surveys were displayed in Figures B.1-5, B.1-6, B.1-8, and B.1-9.

When modeling individual days on which the dye and turbidity surveys were performed, the Aqueduct model was typically started several hours before the initiation of dye injection or solids discharge, near the preceding high or low slack water.

Eddy Viscosity

The principal calibration parameters in RMA2 are eddy viscosity and channel roughness. Eddy viscosity (E) controls the fluid momentum transfer between water masses moving at different speeds. The eddy viscosity in the Aqueduct model was assigned by allowing the model to automatically adjust E after each iteration based upon a Peclet number. The Peclet number defines the relationship between velocity, elemental length, fluid density, and eddy viscosity. The Peclet number (P) is recommended to be between 15 and 40, and the formula that relates P to eddy viscosity is given as:

$$P = rho\ U\ dx\ /E$$

Where
rho = fluid density (kg/m^3)
U = average elemental velocity (m/sec)
dx = element length (m)
E = eddy viscosity (Pascal-sec)

As the Peclet number is increased, the eddy viscosity decreases. A Peclet number of 20 was determined to provide numerical stability in the RMA2 model over a range of flow and tidal conditions.

Cross-Sectional River Velocity

The Manning's coefficient option was selected for determining channel roughness in the RMA2 model. The user has the choice of entering a uniform Manning's coefficient or providing a relationship where the Manning's coefficient varies as a function of water depth. Providing a higher Manning's coefficient for the shallower off-channel area, and a lower Manning's coefficient in the deeper channel, increases the velocity difference between these two regions. This velocity variation as a function of depth was most noticeable during the 6-7 April 2000 cross-sectional velocity surveys (Section B.1-2, Table B.1-1) at Transect B3. The RMA2 model was executed for 6 and 7 April 2000 and the resulting velocities along Transects B3 and B4 were compared to observations. This comparison is illustrated in Figure B.2-3 for Transect B3 and Figure B.2-4 for Transect B4. The Manning's distribution selected for use in the model has the following form.

River Depth (m)	Manning's Coefficient
.5	0.047
2	0.035
4	0.030
6	0.027
10	0.024
14	0.023
16	0.021

At depths greater than 6 meters, the Manning's coefficients in the above table are similar to those contained in RMA2 as a default setting based on San Francisco Bay.

B.2.3 Calibration of Diffusion to the Dye Survey Data (RMA4)

Longitudinal and lateral diffusion were calibrated by fitting RMA2/RMA4 to the dye plume mapping data obtained on 2 May 2000 at Outfall 003 (Georgetown Reservoir) and 24 May 2000 at Outfall 002 (Dalecarlia Basin).

On 2 May 2000 (Outfall 003, Georgetown Reservoir), the model was started at 0600 hour (near high slack) approximately 2.0 hours before Outfall 003 was turned on and the initiation of dye injection. As discussed in Section B.1.6 (Table B.1-8), the average discharge flow during the reservoir drawdown was 3.46 cms. The dye concentrations used in the model are provided in the upper portion of Table B.1-8. During the 6-hour dye release, discharge dye concentrations varied between 14.2 ppb and 21.2 ppb. Because of the travel time between the reservoir outflow and the river, the times for the changes in effluent concentration were lagged slightly in the model. Due to the uncertainty associated with the approximately one-half hour period when there was no dye injection (1240-1310 hrs, Table B.1-8), a low 5-ppb concentration was used during this interval.

On 24 May 2000 (Outfall 002, Dalecarlia Basin), the model was started at 0600 hour (near low slack) approximately 2.0 hours before Outfall 002 was turned on and the initiation of dye injection. As discussed in Section B.1.6 (Table B.1-10), the average discharge flow during the reservoir drawdown was 1.73 cms. The dye concentrations used in the model are provided in the upper portion of Table B.1-10. During the 6-hour dye release, discharge dye concentrations varied between 18.1 ppb and 34.2 ppb. Because of the travel time between the reservoir outflow and the river, the times for the changes in effluent concentration were lagged slightly in the model.

Diffusion coefficients were selected using a model option that automatically generates a value at every time step for each element based on the element size and average current velocity. The x-direction current velocity is set along the direction of the average flow in the element. The calculated diffusion value is scaled by a factor input by the user. For the Aqueduct model, a x-direction scale factor of 0.2 was used, which was within the recommended range. The y-direction diffusion coefficient is set as a fraction of the x-direction coefficient. The process of fitting the RMA4 model to the dye plume mapping data showed that the selection of the y-direction diffusion scale factor was important for reproducing the observed dye distribution. Beyond the immediate vicinity of Outfall 003, a y-direction scale factor of 0.15 was used throughout the model. This means that the y-direction diffusion coefficient was equal to 15-percent of the x-direction coefficient, a value within the recommended range. Downstream of Outfall 003, the predicted dye plume traveled along the shallow near-shore region with higher near shore concentrations than observed in the field. It was necessary to increase the y-direction scale factor along this near shore region in order to decrease concentrations and achieve agreement with measured observations. The y-direction scale factor was increased in two regions associated with Outfall 003; the first being a 40x40-m region directly in front of Outfall 003, and the second region extended 620-m downstream and approximately 80-m offshore along the shallow near shore zone. In the region directly in front of Outfall 003, a y-direction scale factor of 0.4 was used to achieve agreement with the observed initial dilution. Within the second near shore region, a y-direction scale factor of 0.25 was used (25 percent of the x-direction diffusion coefficient). This shallower near shore region contains lower velocities and subsequently the x-direction diffusion coefficients selected by the model are smaller than values further out in the river.

For the 24 May 2000 dye simulation, the x-direction diffusion scale factor was maintained at 0.2 throughout the model domain and the y-direction scale factor was maintained at 0.15 beyond the vicinity of the outfalls. Downstream of Outfall 002 the y-direction scale factor had to be increased to 0.7 for a 420-m reach in order to obtain the lateral nearly mixed condition observed at Transect 1 (Figure A.3-1). The 0.4 and 0.25 y-direction scale factors that were used in the near shore region downstream of Outfall 003 were not necessary for the Outfall 002 simulation. The model parameters used in the resulting four regions of the model are summarized in the following table.

Region	**Peclet**	**x-Dir Scaling**	**y-Direction Scaling**	
			002 Simulation	**003 Simulation**
1) Main Model	20	0.20	0.15	0.15
2) Downstream 002	20	0.20	0.70	0.70
3) Adjacent 003	20	0.20	0.15	0.40
4) Downstream 003	20	0.20	0.15	0.25

A comparison of predicted and observed dye concentrations at the survey transects for the 2 May 2000 Outfall 003 study (Georgetown Reservoir) are provided in Figures B.2-5 and B.2-6. A comparison of predicted and observed dye concentrations for the 24 May 2000 Outfall 002 study (Dalecarlia Basin) are provided in Figures B.2-7 to B.2-9. At each transect the figures illustrate the dye distribution from let to right bank when facing downstream.

Outfall 003 (Georgetown Reservoir)

Figure B.2-5 illustrates the agreement between observations and model predictions at Transect 9, 70-m downstream of Outfall 003, and Transect 12, 900-m downstream. At Transect 9, the build-up of the dye plume is illustrated between surveys 1 and 3. During survey 3, the model correctly predicted higher concentrations along the offshore edge of the eddy with lower concentrations towards shore. Farther downstream at Transect 12 (Figure B.2-5) the dye distribution is much smoother and there is very good agreement between predicted and observed values both at the shoreline and in the lateral distribution.

Figure B.2-6 illustrates the agreement between observation model predictions at Transects 14 and 16 during survey 3 and 5. At both transects the model provides very good agreement with observations for both the near shore concentrations and the lateral dye distribution across the river. At Transect 16 during survey 3, dye is just beginning to arrive, and by survey 5, concentrations have increased, particularly along the discharge (left) bank. A comparison of Transects 12, 14, and 16 illustrates the mixing of the plume towards the far (right) bank with increasing downstream distance.

Outfall 002 (Dalecarlia Basin)

A comparison of predicted and observed dye concentrations illustrating the calibration of the RMA4 model at Outfall 002 is provided in Figures B.2-7 to B.2-9. Figure B.2-7 illustrates the agreement between observation model predictions at Transects 1 and 3. By Transect 3, both the model and observations are fully mixed laterally and there is very good agreement on the amount of dye build-up between surveys. The higher observed dye concentrations at Transect 1 during survey 3 may indicate that the river is not yet fully mixed vertically at this upstream location.

Figure B.2-8 displays dye results at Transects 6 and 10 during surveys 2, 3, and 4. During survey 2 at Transect 6 and survey 3 at Transect 10, the dye arrived slightly faster than indicated by the model. However, model predictions during subsequent surveys at Transects 6 and 10 were in very good agreement with observations. Transects 6 and 10 are both downstream from a location were the river increases in width and the resulting dye distributions illustrate the lateral mixing from higher values in the main channel (right bank) towards the shallower region (left bank). Figure B.2-9 displays predicted and observed dye distributions at Transects 12 and 14, and similarly illustrates the build-up of dye between surveys and the decreasing concentrations toward the shallower left bank.

Transect Averaged Dye Distribution

An additional way for comparing differences between observations and model predictions is provided by examining the lateral average dye concentrations at each transect. The lateral average dye concentrations during the plume surveys were summarized in Table B.1-9 at Outfall 003 and Table B.1-12 at Outfall 002. The corresponding lateral average dye concentrations were calculated from the model output and are displayed in Figure B.2-10 at Outfall 003 and Figure B.2-11 at Outfall 002 for surveys 2 to 5. The Outfall 002 dye survey (Figure B.2-10) shows excellent agreement between observed and predicted values as the leading edge of the dye distribution traveled downstream from survey to survey.

At Outfall 002 (Figure B.2-11), the longitudinal dye distribution was in good agreement during surveys 2 and 3 while the dye traveled 4,000 meters downstream. During surveys 4 and 5, at downstream distances of approximately 4,500 to 6,500 meters, the modeled dye lagged observations by several hundred meters. This region 4,500 to 6,500 m downstream of Outfall 002 corresponds to a region downstream of Outfall 003 where the lateral average dye concentrations were in good agreement. The Outfall 002 dye plume was primarily moving along the main channel, while the Outfall 003 dye plume was in the shallower off-channel region. This may indicate that the model slightly under estimates main channel velocities in this downstream region.

B.2.4 Modeling the Suspended Solids Plume (SED2D)

The suspended solids discharge from the Georgetown Reservoir (Outfall 003, 3 May 2000) and Dalecarlia Basin (Outfall 002, 25 May2000) were modeled with SED2D. SED2D requires the RMA2 hydrodynamic output file, diffusion coefficients, and the particle characteristics of the material being discharged.

SED2D Diffusion

The characterization of diffusion in SED2D varied from RMA4. While RMA4 used a scaling factor, SED2D used a Peclet number similar to the way eddy viscosity was treated in RMA2. The intent during model development was to use diffusion as calibrated with the dye surveys for both RMA4 and SED2D. SED2D diffusion similar to that used in RMA4 was determined by executing SED2D for a range of Peclet numbers. These SED2D scenarios used a very fine particle with a very low fall velocity that essentially behaved as a conservative tracer similar to the conservative dye in RMA4. A Peclet number of 10 was determined to match the RMA4 dye results at Outfall 002 and 003. The Peclet number is used to determine the x-direction diffusion. The y-direction diffusion is calculated as a fraction of x-value, similar to RMA4. The same y-direction scaling factors were used in SED2D as in RMA4 including 0.25 and 0.4 in the vicinity of Outfall 003, 0.7 downstream of Outfall 002, and 0.15 throughout the remainder of the model.

Particle Characteristics

The composite particle size distribution based on sediment samples collected during this project from the Georgetown and Dalecarlia Reservoirs indicated that the material was 65.7 % sand, 22.0 % silt, and 12.3 % clay (Table B.1-6). However, this particle distribution does not reflect the presence of the floc resulting from the addition of alum in the water treatment process. An analysis of particle size without using a de-floccing agent (which is typically used in particle size determinations) yielded a much narrower range of particle size with an absence of the finer clays (Table B.1-7).

Modeling the discharged material as a single particle classification (floc) was not considered to be realistic because considerations of all the available data indicated that a coarser and finer material were also likely to be present. Even though the results in Table B.1-7 for a spherical particle did not indicate the presence of sand (> 0.05 mm), coarser sand was observed in the bottom of the settling column during the test on the floc. Based on this observation, an assumption that 25 % of the discharged material existed as sand was considered to be reasonable. The remaining 40.7 % of the 65.7 % sand fraction in Table B.1-6 would be associated with the floc.

During the settling test on the floc, it is also believed that any finer particles present were entrained earlier in the test, and therefore were not observable at the longer settling times normally associated with finer silt and clay. To provide for a finer particle classification, it was assumed that 10 % of the discharged material was present as silt. The remaining 24.3 % of the 34.3 percent silt/clay fraction in Table B.1-6 would be associated with the floc.

The particle size distribution from the settling tests and the particle scenario selected for the model are summarized in the following table.

ASTM Test Results				**Model Scenario**		
Material	**Dia (mm)**	**ASTM (%)**	**Floc (%)**	**Material**	**Dia (mm)**	**Percent**
Sand	> 0.05	65.7	88.2	Sand	> 0.05	25
Silt	0.002-0.05	22.0	11.8	Floc	> 0.05	65
Clay	< 0.002	12.3	0	Silt	< 0.05	10

SED2D provides different mechanisms for the simulation of noncohesive particles (sand) and cohesive particles (silt and clay). The floc was modeled using the cohesive particle mechanism. For sand, the model requires the particle diameter, settling velocity, and material density. For a cohesive particle, the model requires settling velocity and shear stresses for deposition and erosion. SED2D calculates a bottom shear stress as a function of velocity and channel friction at each location in the model. The bottom shear stress must be below the depositional shear stress for a particle to be deposited. If the bottom shear stress increases above the erosional shear stress, a particle will be resuspended.

The relationship between particle size, shear stress, and other physical site conditions effecting sediment transport is under active investigation by the U.S. Army Engineer Waterways Experiment Station (WES) and other investigators. WES has indicated that provided a sufficiently wide initial particle size distribution, fine-grained sediment is sorted by particle size during deposition. Both settling velocities and critical shear stresses for deposition vary sharply between silt and clay fraction. Particle size has not been well correlated to the readability of cohesive fine-grained sediments. On tests performed on sediments from New Bedford Harbor (UASCE 1993) the critical shear stress for deposition was found to be 0.043 n/m^2 (newton/m^2) for particles < 0.014 mm, and 0.33 n/m^2 for particles between 0.014-0.028 mm. The critical shear stress for erosion was slightly higher: 0.06 n/m^2 for particles < 0.014 mm and 0.38 n/m^2 for particles 0.014-0.028 mm. At larger particle sizes the critical shear stress for deposition increased more slowly, to 0.42 n/m^2 for particles 0.028-0.074 mm.

A paper on tidal resuspension of sediments in the Chesapeake Bay (Sanford et al, 1991), reported that the majority of tidally eroded material was redeposited locally during slack tide. Thus tidal erosion probably accounted for a relatively small part of the observed net sediment loss. The paper concluded that a more likely cause of massive erosion is the combination of tidal and wind driven current with wave-induced velocities and pressure fluctuations during storms. Sanford (1991) also indicated that critical shear stresses for erosion on the order of 0.1 n/m^2 are commonly reported in the literature. Sanford (personal communication) recommended that a critical shear stress of 0.1 n/m^2 be used for both deposition and erosion.

Based upon a review of the particle data, the following particle attributes were used in the model.

Particle Characteristics

Parameter	**Sand**		**Parameter**	**Floc**	**Silt**
Diameter (mm)	0.05		Diameter (mm)	.05	.002
Settling Vel.(m/sec)	0.00208		Settling Vel. (m/sec)	2.4E-4	8.2E-5
Density (gm/cm^3)	2.5		Shear Stress (newton/m^2)	0.1	0.1

SED2D Model Execution

SED2D was executed three time for each of the two outfalls to provide model simulations for the sand, floc, and silt particle classes. The water column TSS concentrations for the three particle classes were summed at each model node to provide composite TSS concentrations. In general, the TSS discharge concentration was modeled as being 10,000 mg/L using a 0.132-cms flow at Dalecarlia Basin and a 1.138-cms flow at Georgetown Reservoir. A 3.5-hour suspended solids discharge event was modeled at both outfalls.

There was an alteration to the 10,000 mg/L for 3.5-hour discharge scenario at each outfall. On 3 May 2000 at Outfall 003, the discharge was temporarily turned on between 0915 hrs and 0938 hrs, before the main clean-out event started at 1004 hrs. This pre-release was included for two 15-minute model time steps. On 25 May 2000 during survey 2 of the Outfall 002 study, the observed TSS concentrations at the upstream transects were underestimated by the model. The clean-out of solids from a reservoir is not a continuous process and the 10,000-mg/L TSS discharge concentration assumed at Outfall 002 was based on individual measurements varying between 4,600 mg/L and 16,500 mg/L. In keeping with this expected variability, the TSS discharge concentration was temporarily increased prior to survey 2. A summary of the total mass discharged at each outfall, including the alterations from a uniform scenario, is provided in the following table.

Mass of Discharged Solids (kg)

Material	Outfall 002 (Dalecarlia)	Outfall 003 (Georgetown)
Sand	4,455	38,407
Floc	11,583	99,860
Silt	1,782	15,363
Total	17,820	153,630

The surface area of Georgetown Reservoir (66,425 m^2) is approximately 11 times greater than the surface area of Dalecarlia Basin 3 (5,897 m^2). The increase in mass of solids discharged at Outfall 003 is approximately proportional to the increase in reservoir size.

A frequency distribution of suspended load at Chain Bridge, based on historical USGS data, is presented in Chapter 4 (Section 4.3.2, Table 4-5). The 17,820-kg discharged solids mass at Outfall 002 is less than a lower 10-percentile value of the daily Potomac River suspended load. The 153,630-kg discharged solids mass at Outfall 003 is between a 40- and 45-percentile of daily Potomac River suspended load.

A comparison between observed surface and predicted TSS values is provided in Figures B.2-12 and B.2-13 for Outfall 002 from Dalecarlia Basin, and in Figures B.2-14 and B.2-15 for Outfall 003 from Georgetown Reservoir. The SED2D model output only contained the TSS loadings from the outfalls and did not include the natural background concentrations in the Potomac River. This was done to allow the model to illustrate the incremental increase in TSS concentration directly associated with operations at the reservoirs. However, to make comparisons to the observed survey data, a background TSS concentration was added to the model predictions when generating the figures. The background concentrations were selected based upon examination of the survey data. For the 3 May 2000 survey at Outfall 003, a background TSS concentration of 8 mg/L was used at Transects 10 to 14, decreasing to 6 mg/L at Transect 16. For the 25 May 2000 survey at Outfall 002, a background TSS concentration of 8 mg/L was used at Transects 1 to 8, decreasing to 6 mg/L at Transect 10, and 3 mg/L at Transect 12. The observed TSS data in Figures B.2-12 to B.2-15 was smoothed using a 3-point rolling average.

When comparing observed and predicted TSS concentrations in Figures B.2-12 to B.2-15 several considerations need to be kept in mind.

- In areas where there is a shallow near-shore zone, such as downstream of Outfall 003, background TSS was observed to decrease between the main-channel (right bank) and the shallower (lower velocity) left bank. In the following figures, the uniform background concentrations added to the model predictions was representative of the higher main channel TSS values. As a result, in the near-shore region observed TSS values decrease below this background level. In these areas, greater attention should be given to the relative difference between scenarios than their absolute values.

- The TSS discharge had a density greater than the receiving water and could be expected to create a sinking plume with a stronger influence in the lower portion of the water column. As a result, the near surface observations may underestimate the water column averaged SED2D predictions. This effect was particularly noticeable at the near-field transects in the vicinity of Outfall 003.

- The turbidity probe, mounted on a fixed strut on the survey boat, was effected by surrounding turbulence that resulted from changes in boat speed and wave action. The downstream transects (> Transect 12) were in a wider, more open portion of the Potomac

River with larger waves and the survey boat may have been operated at a slightly higher speed. These site conditions may have contributed to TSS variability at some transects.

Outfall 002, Dalecarlia Basin

As previously discussed, the solids discharge event at Outfall 002 on 25 May 2000 lasted for approximately 3.5 hours. The event was modeled assuming a 10,000-mg/L TSS concentration and a 0.132-cms discharge flow. A total solids mass of 17,820 kg was discharged. The model results for sand (25%), floc (65%) and silt (10%) were combined to determine a total TSS concentration. A comparison between observed and predicted TSS concentrations are provided in Figures B.2-12 and B.2-13.

Figure B.2-12 displays good agreement between predicted and observed TSS concentrations at Transects 1 and 4 during surveys 2, 3, and 4. Surveys 3 and 4 were performed after the solids clean-out event had ended. At Transect 1, the modeled TSS concentration quickly decreased to background levels during surveys 3 and 4. At Transect 4, TSS concentrations during survey 3 had decreased approximately two-thirds of the way from survey 2 to survey 4 levels. At Transect 4, the relative difference in predicted concentrations between each survey shows good agreement with observations.

Figure B.2-13 displays the TSS build-up at Transect 8 during surveys 1, 2, and 3 and Transect 14 during surveys 2,3, and 4. Transects 8 is located where the river had widened out, providing a lower velocity region near the left bank. The observed data indicates that there is a natural lateral TSS gradient with values decreasing to below 5 mg/L in the quieter waters. This lateral gradient was not incorporated into the 8-mg/L background concentration that was added to the model. At Transect 8, the model correctly indicated that the TSS plume arrived following survey 1, and the TSS increase between surveys 1 and 3 was in good agreement between the model and observations. At Transect 8, the decrease in the survey 1 to survey 3 TSS build-up between the main channel and the left bank has also well represented by the model. At Transect 14, the model correctly indicated that the plume arrived between surveys 3 and 4, and the predicted increase between these two surveys was in very good agreement with the relative difference between observations along the transect.

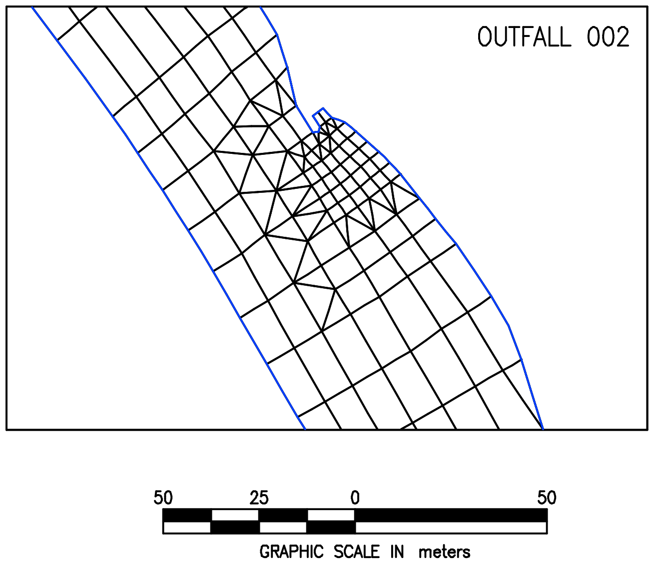
Outfall 003, Georgetown Reservoir

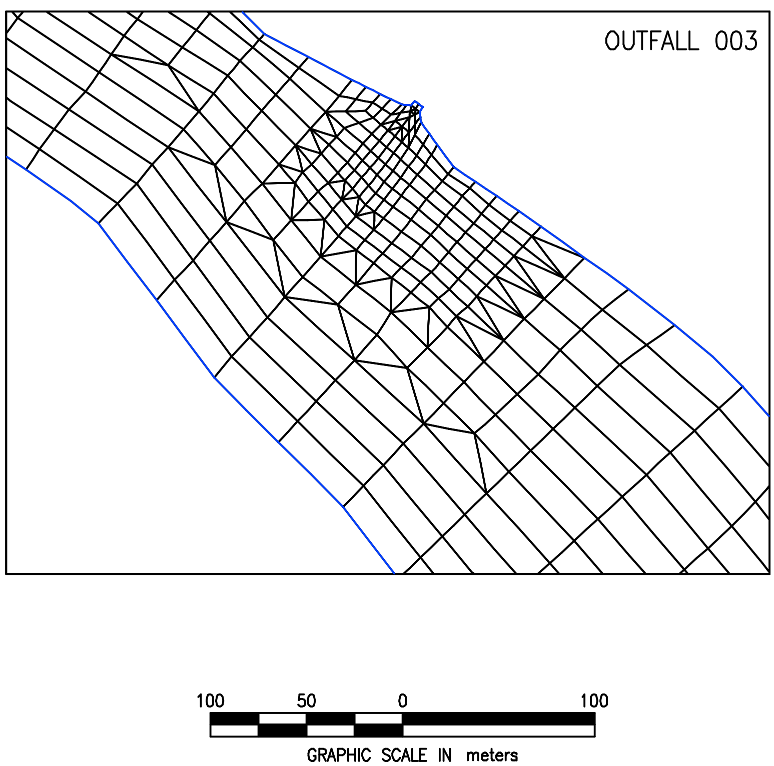
As previously discussed, the solids discharge event at Outfall 003 on 3 May 2000 lasted for approximately 3.5 hours. The event was modeled assuming a 10,000-mg/L TSS concentration and a 1.138-cms discharge flow resulting in a total solids mass of 153,630 kg. The model results for sand (25%), floc (65%) and silt (10%) were combined to determine a total TSS concentration. A comparison between observed and predicted TSS concentrations are provided in Figures B.2-14 and B.2-15.

Figure B.2-14 provides results at Transect 11 (480-m downstream from Outfall 003) and Transect 12 (900-m downstream). At Transect 11, the decrease in TSS concentrations near the left bank and the sharp delineation of the plume width at approximately one-half the river width were well represented by the model. The lower near-shore concentrations and a higher off-shore plume centerline were features associated with a back-eddy. The lower observed concentrations during survey 3, the time of maximum plume build-up, were attributed to water column stratification. Before coming well mixed, the higher density suspended solids plume would result in higher water column average TSS concentrations than would be observed with a near surface probe.

At Transect 12 (Figure B.2-14), maximum plume build-up was reached during survey 3 with the highest TSS concentrations located near shore. The relative concentration increase at the shoreline between surveys 1 and 3 was in good agreement between the model and observations. Off-shore, observed and predicted concentrations were similar, however, the variation in the field data masked the survey-to-survey differences.

Model results at Transect 14 (1700-m downstream), and Transect 16 (2,260-m downstream) are provided in Figure B.2-15. At Transect 14, observed TSS concentrations of 10-15 mg/L during surveys 2 and 3 were in good agreement with the model beyond the near shore region, where agreement is masked by background variation. At Transect 16, observed TSS concentrations were higher on the right side of the river, even during survey 2, which occurred early than the expected arrival time of the plume. It is believed that these higher observed values resulted from a combination of both natural and probe induced background conditions. The downstream transects were in more open water with more wave action. In Figure B.2-15, the relative differences in the middle portion of the river between observed TSS values during surveys 2, 3, and 4 were similar to changes predicted by the model.





FILE: Q:\PROJECTS\6095757\JYOST\FIG2-2-1.DWG

Figure B.2-1. Near-Field Model Grid Used at Outfalls 002 and 003

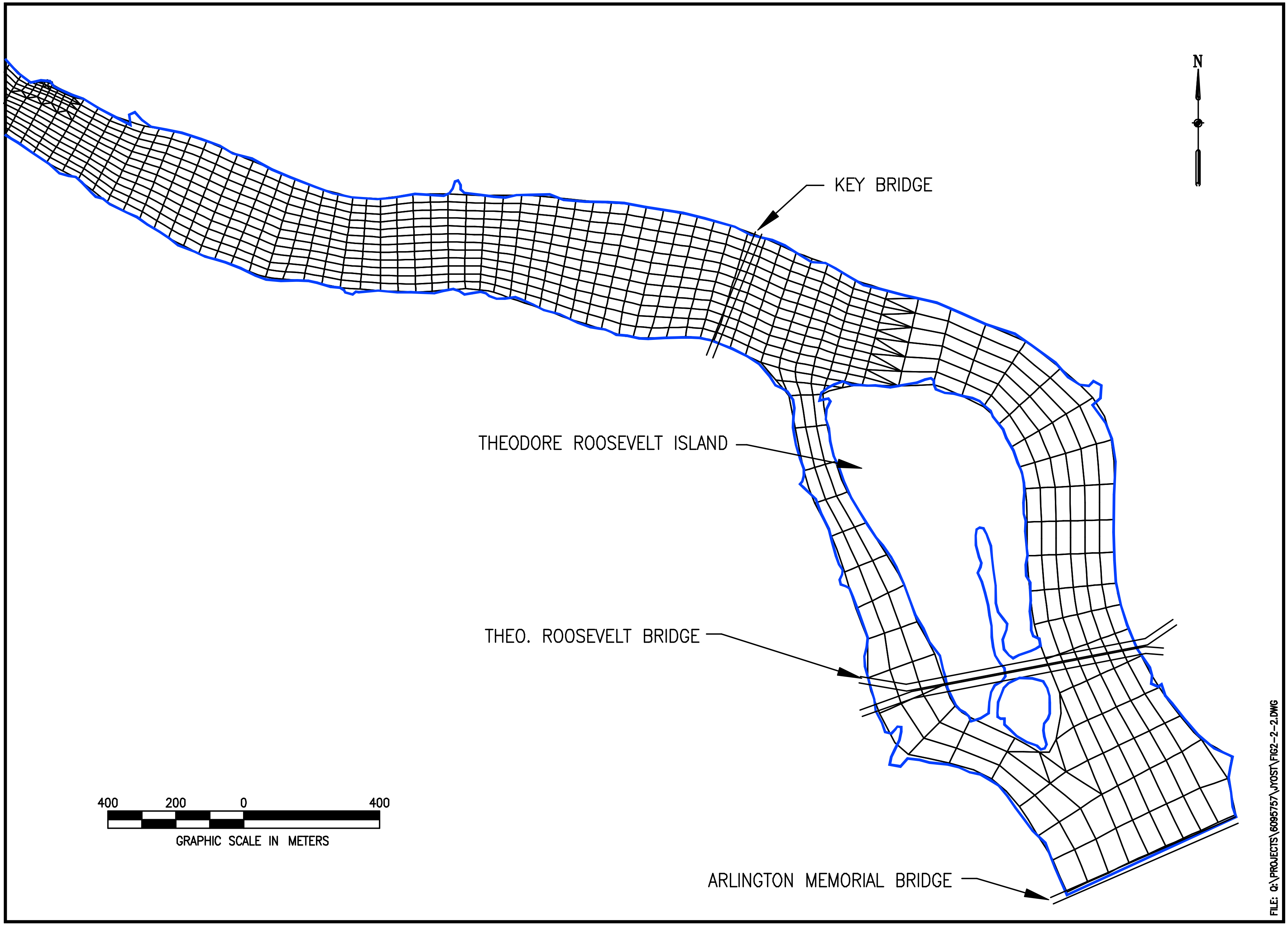


Figure B.2-2. Model Grid Used in the Downstream Portion of the Potomac River Model

Figure B.2-3 Observed and Predicted Potomac River Velocity Along Transect B3, 6-7 April 2000

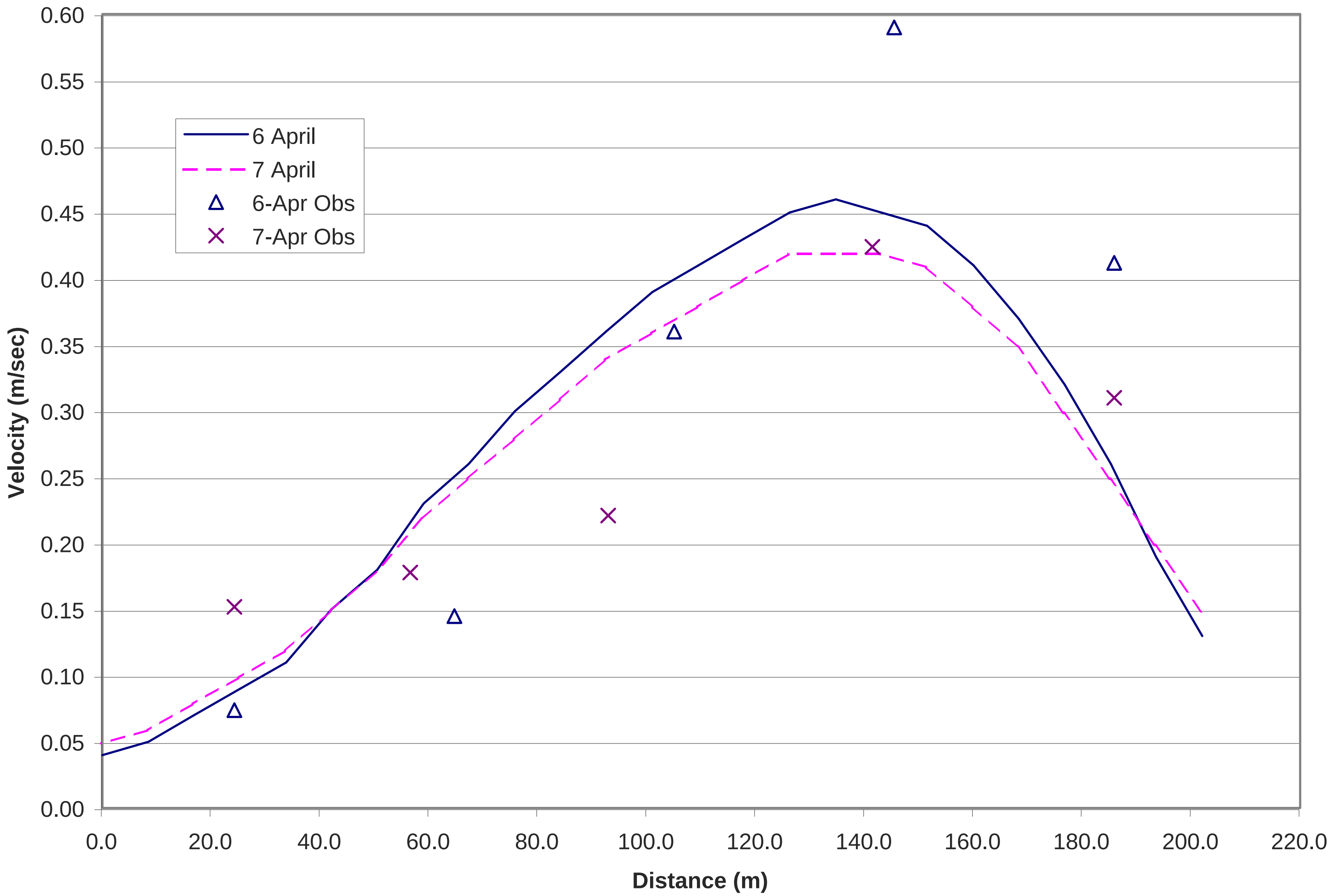
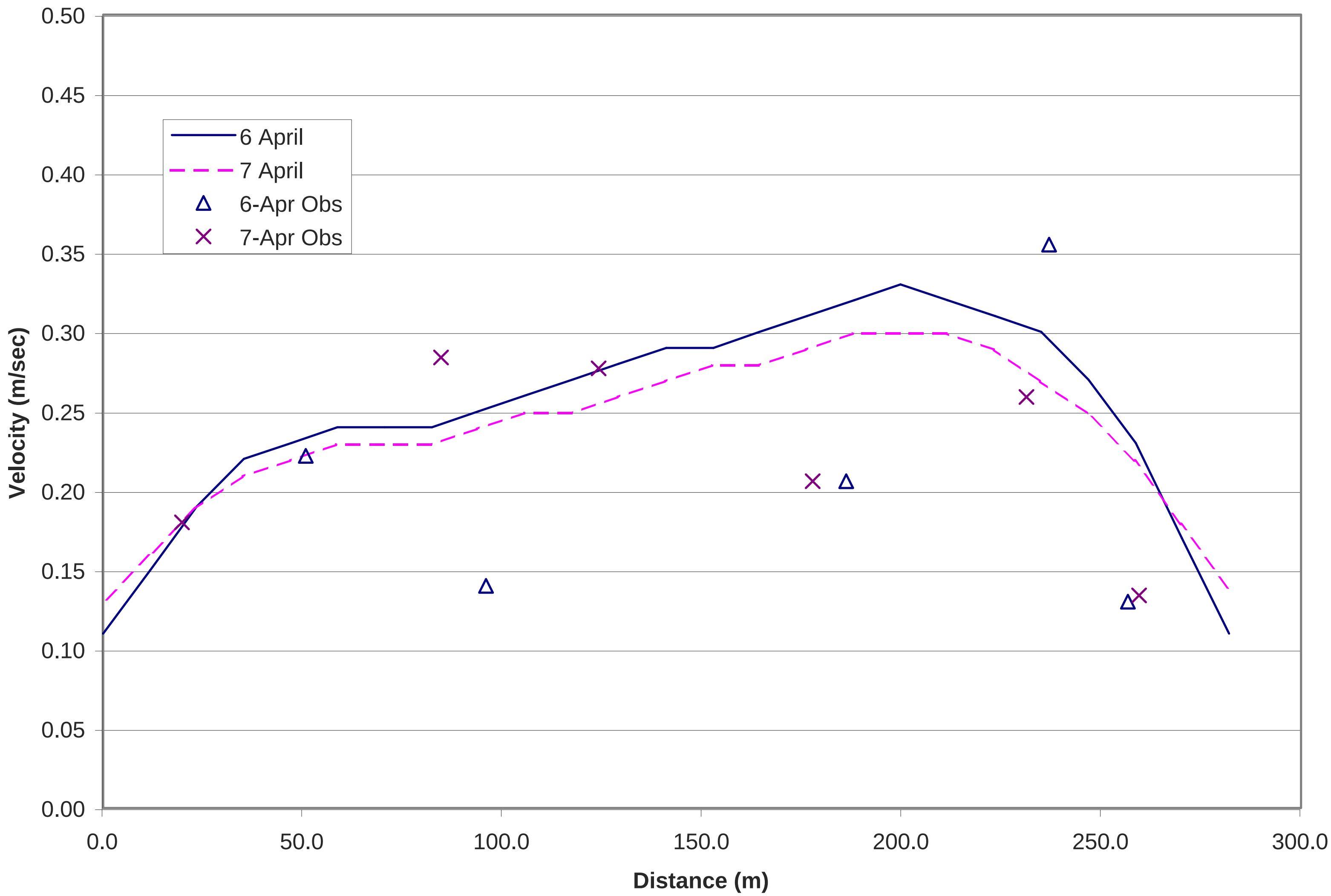
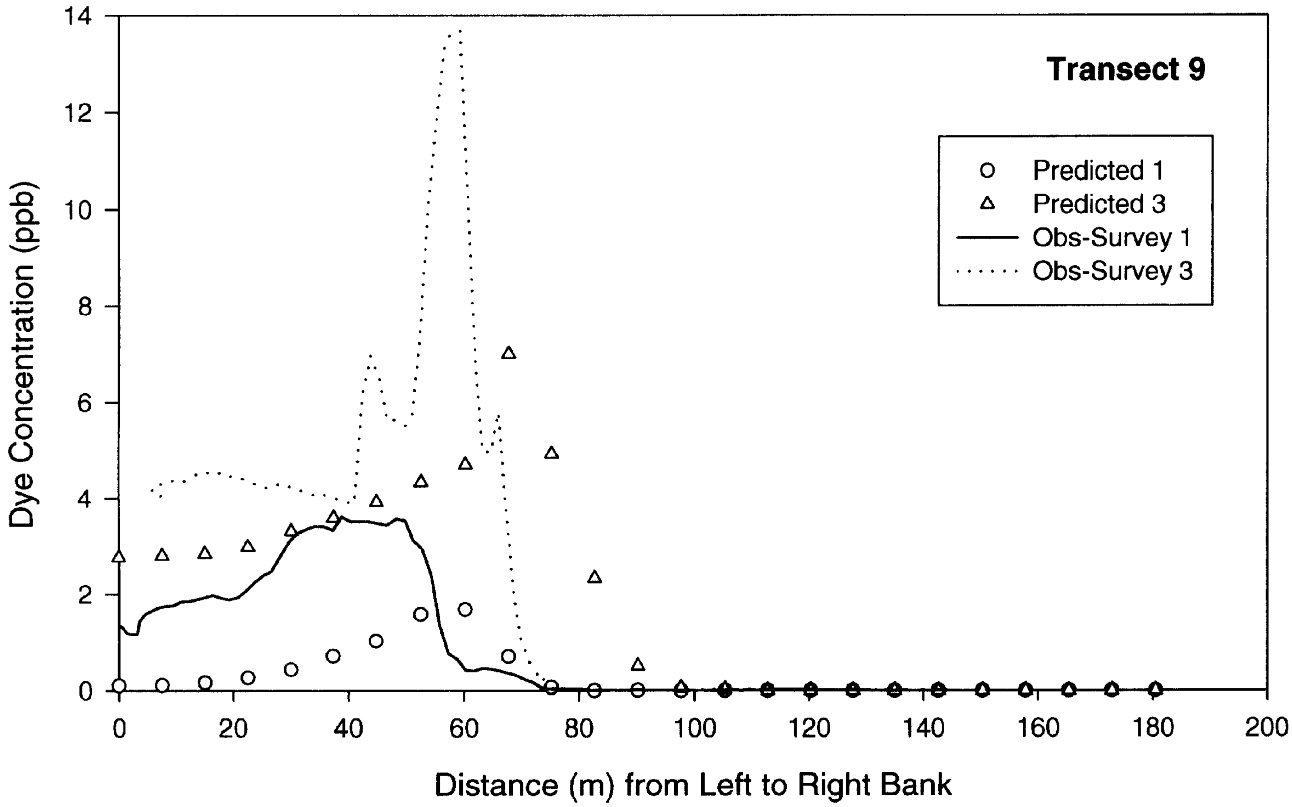


Figure B.2-4 Observed and Predicted Potomac River Velocity Along Transect B4, 6-7 April 2000





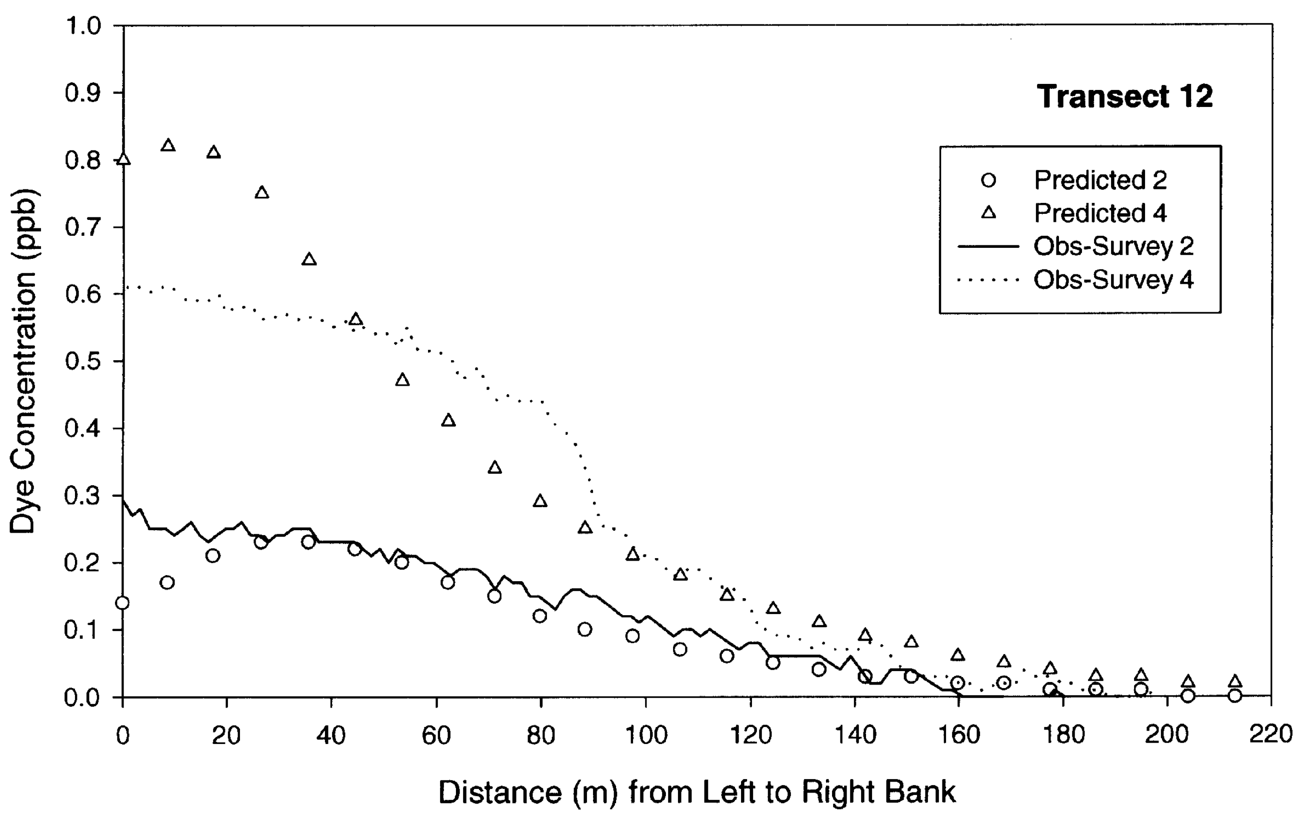
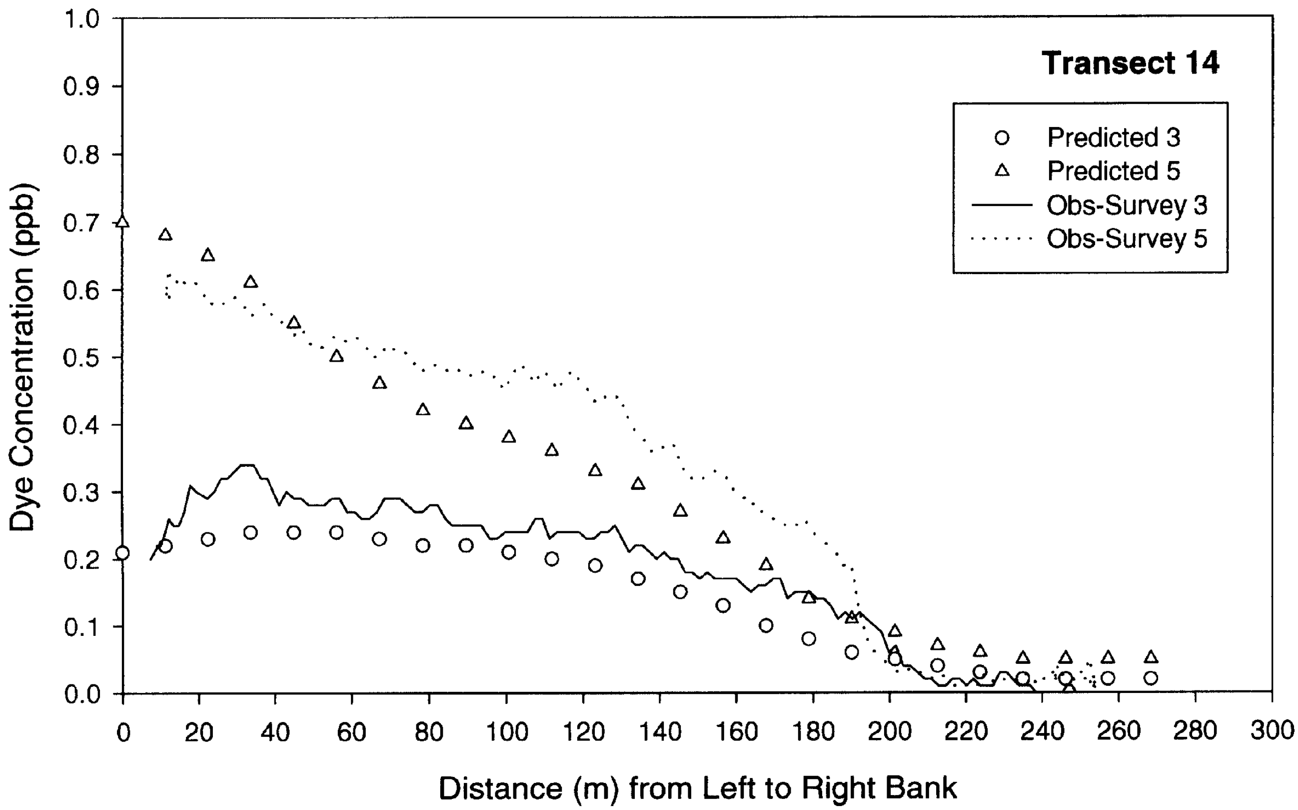


Figure B.2-5 Comparison of Observed and Model-Predicted Dye Concentrations at Transects 9 and 12, Outfall 003, 2 May 2000.



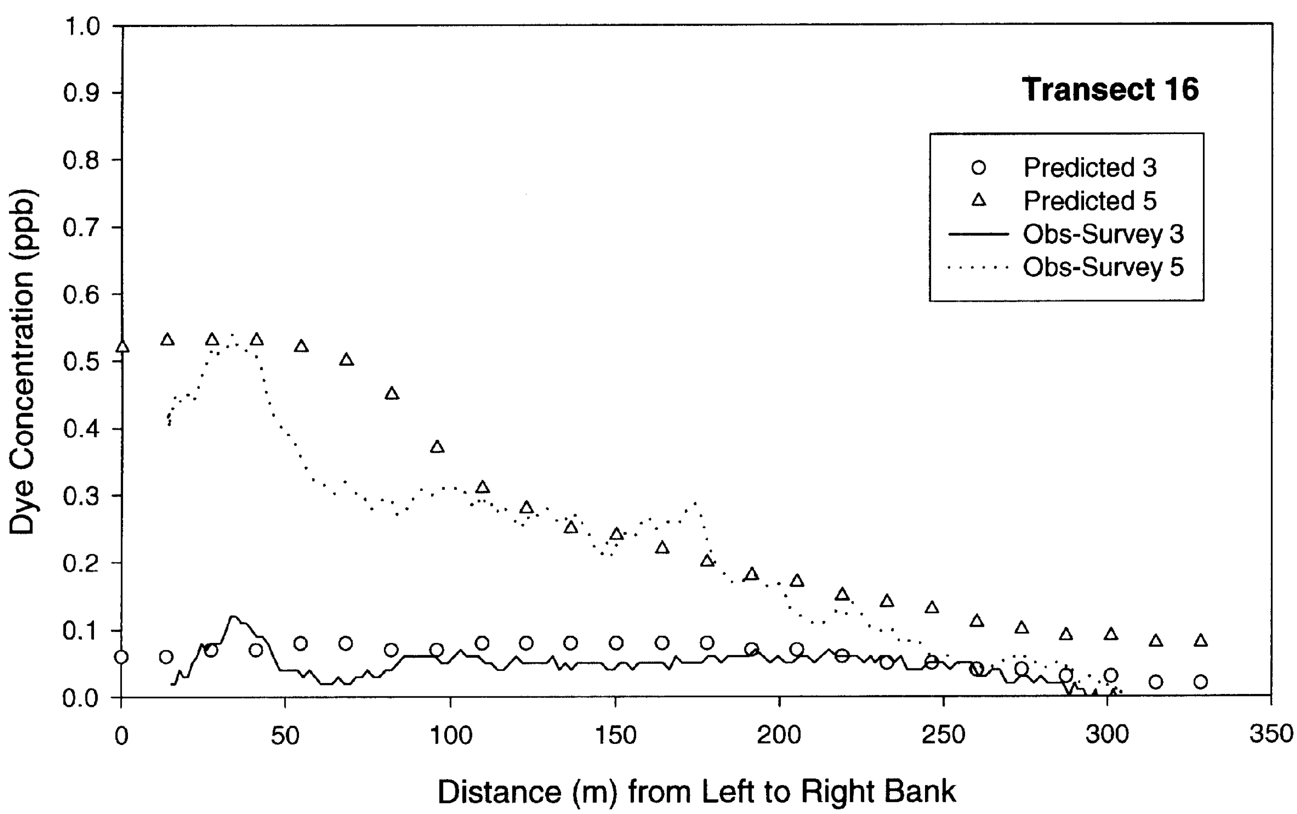
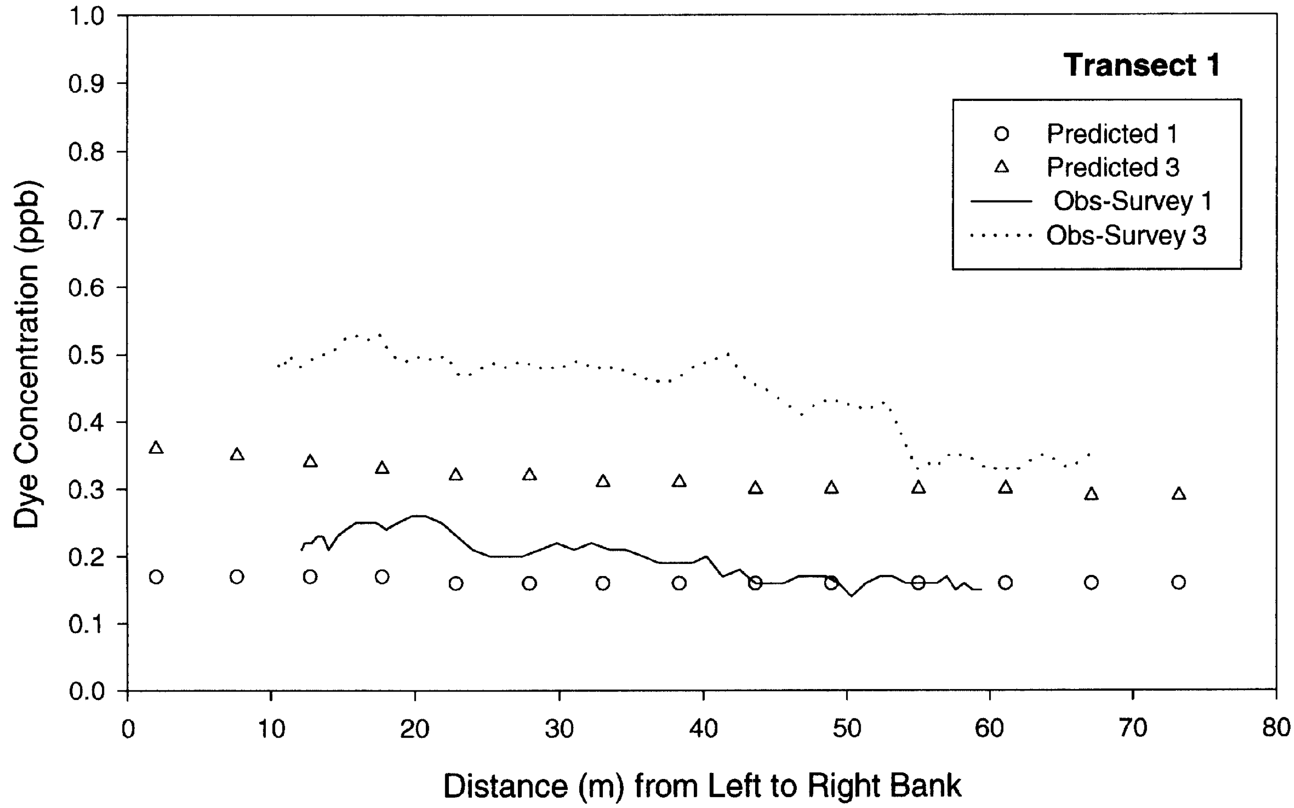


Figure B.2-6 Comparison of Observed and Model-Predicted Dye Concentrations at Transects 14 and 16, Outfall 003, 2 May 2000.



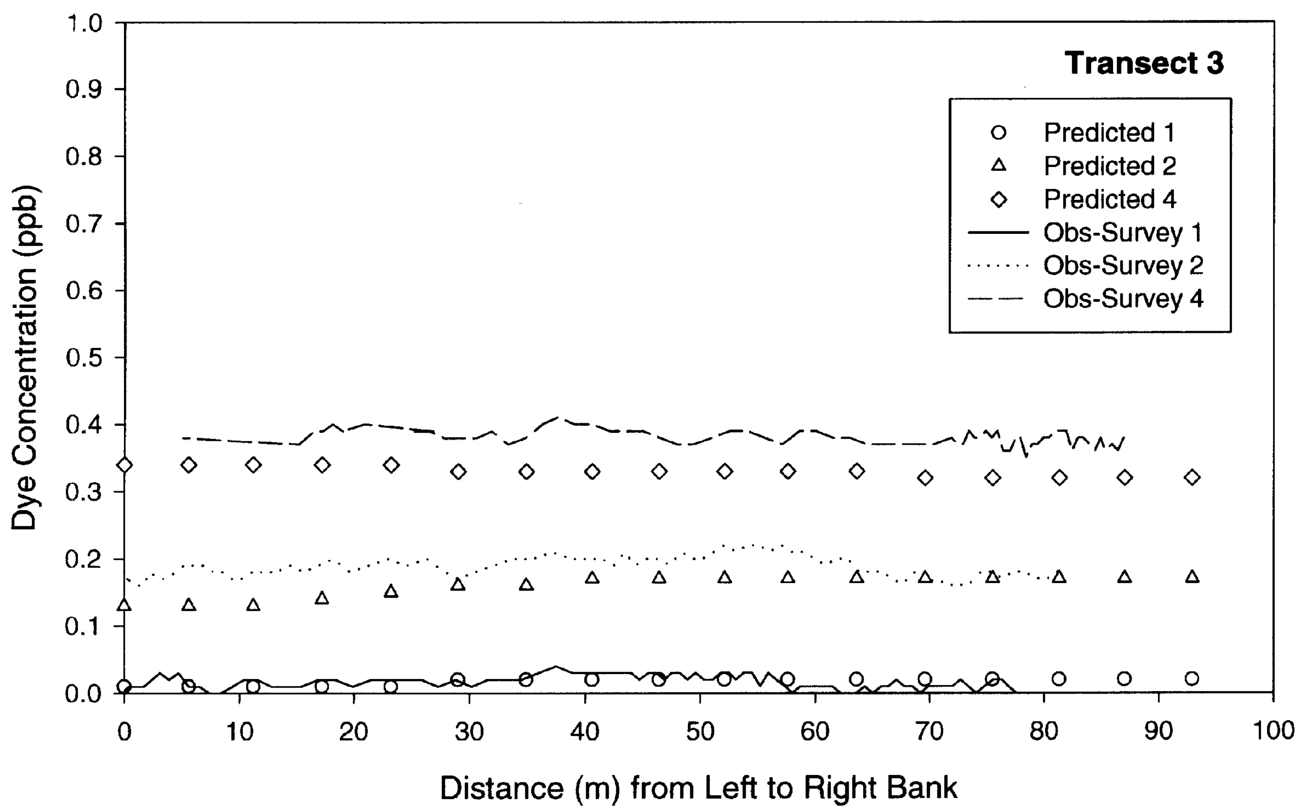
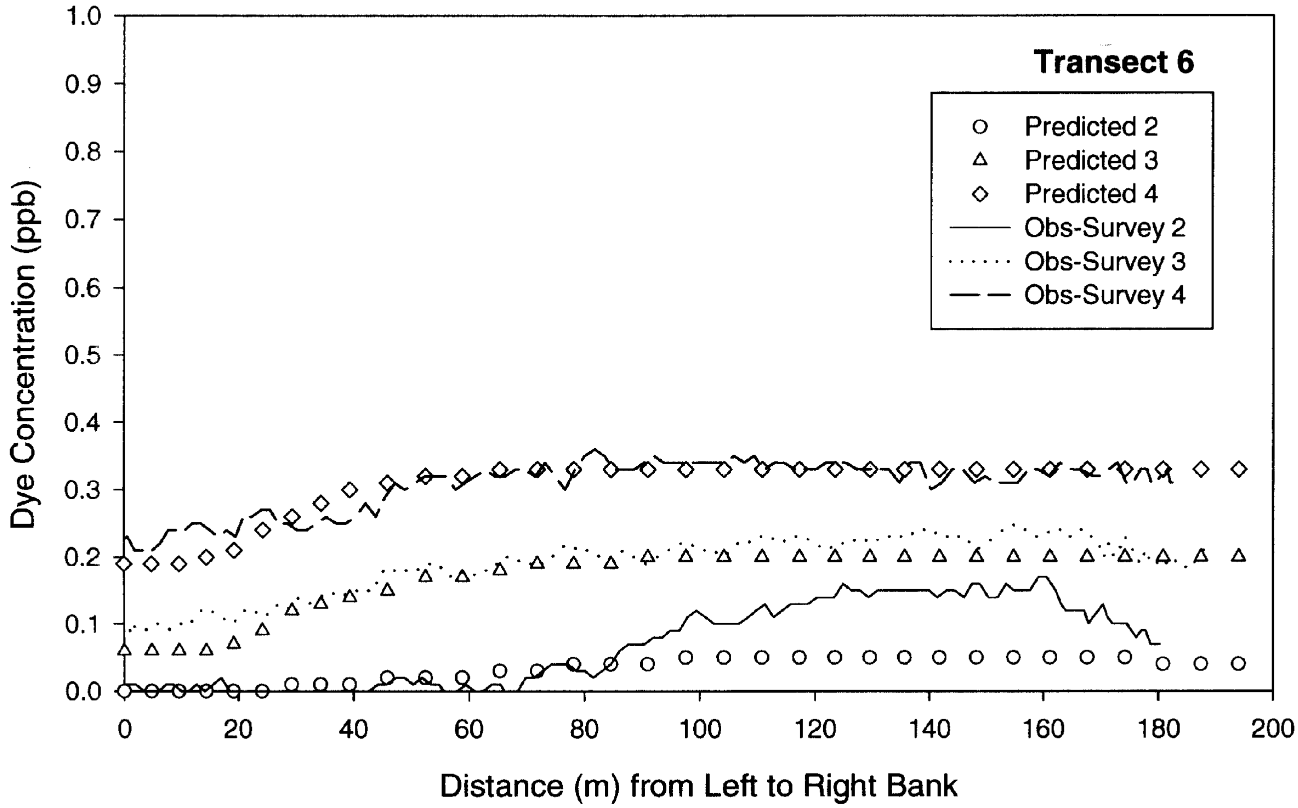


Figure B.2-7 Comparison of Observed and Model-Predicted Dye Concentrations at Transects 1 and 3, Outfall 002, 24 May 2000.



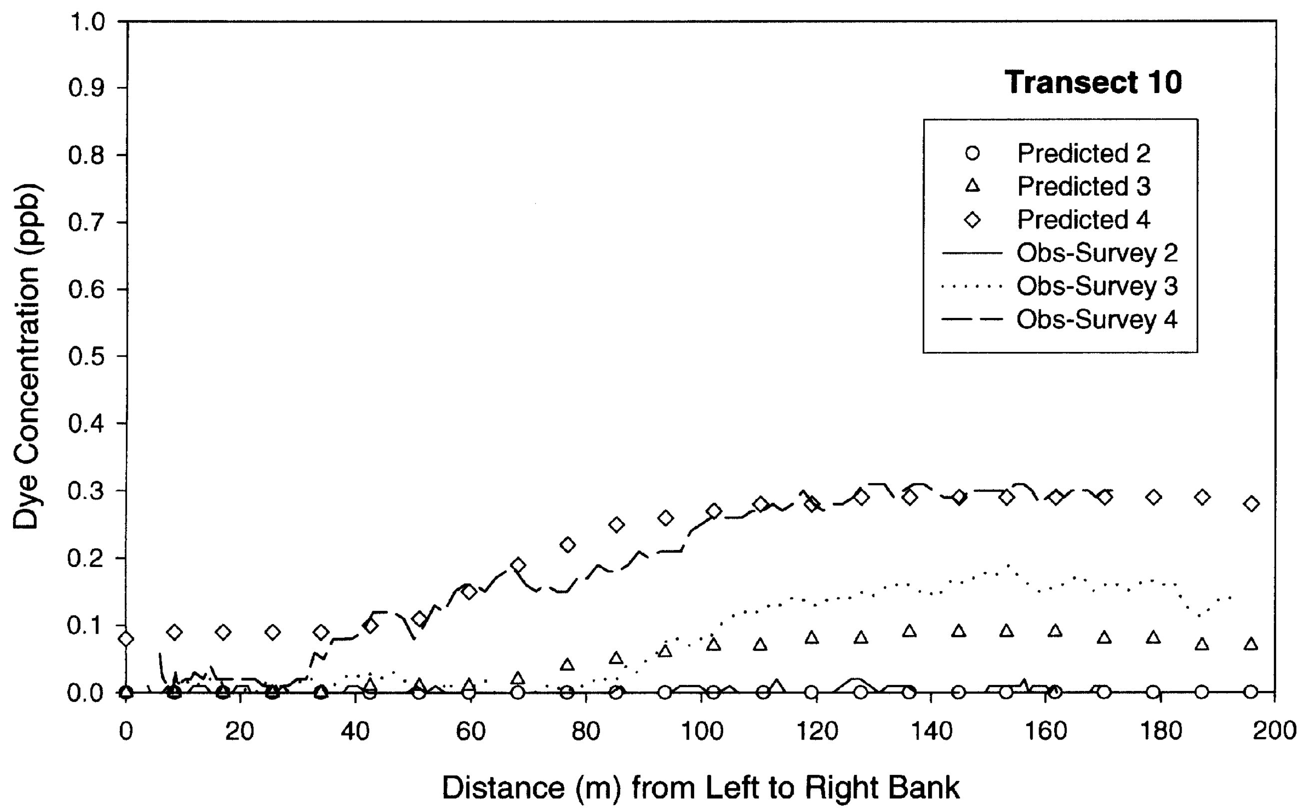
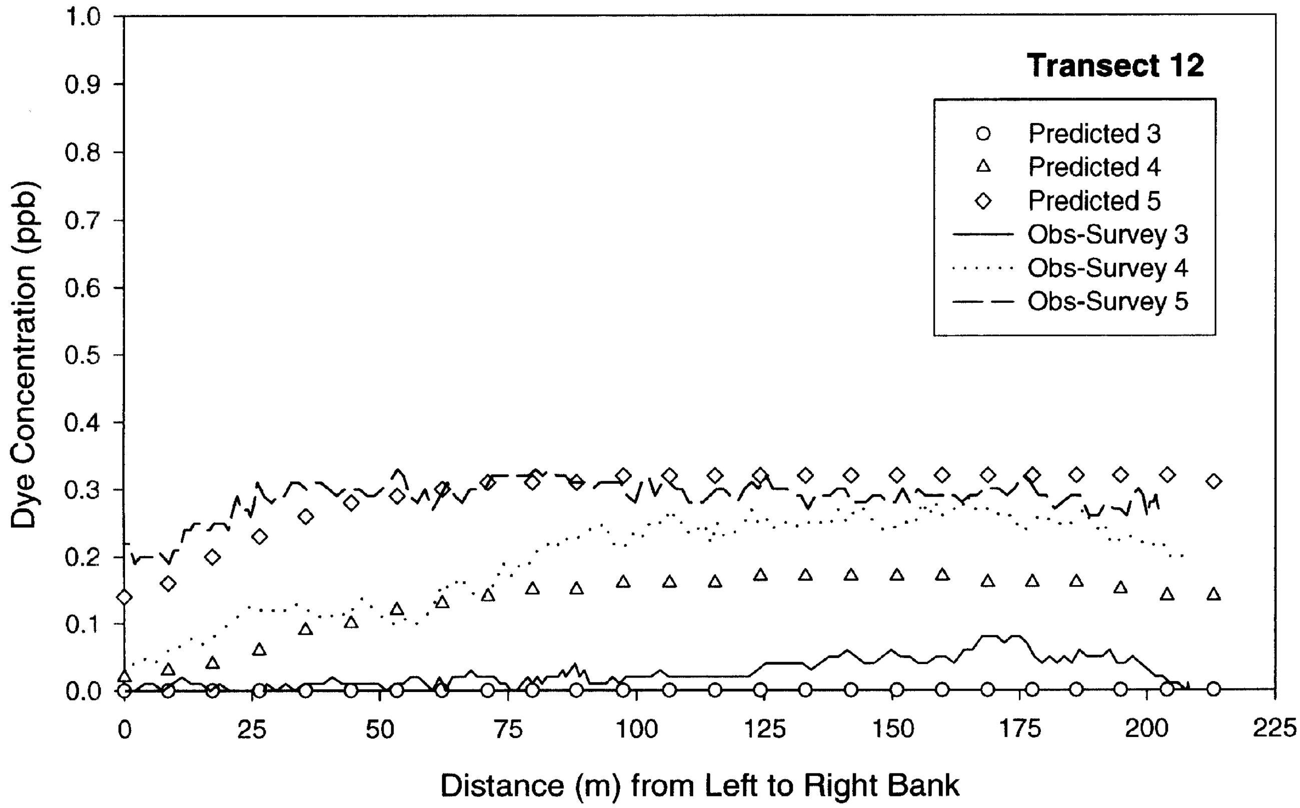


Figure B.2-8 Comparison of Observed and Model-Predicted Dye Concentrations at Transects 6 and 10, Outfall 002, 24 May 2000.



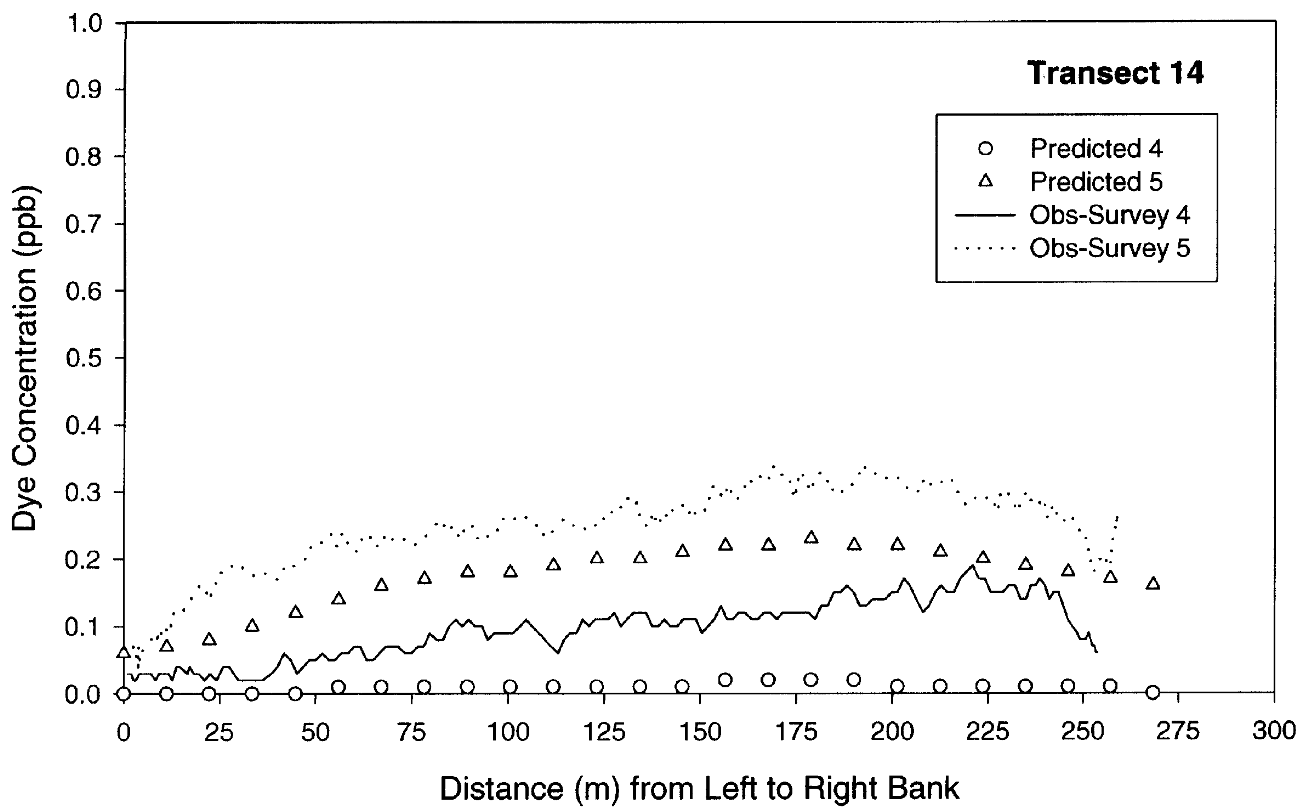


Figure B.2-9 Comparison of Observed and Model-Predicted Dye Concentrations at Transects 12 and 14, Outfall 002, 24 May 2000.

Figure B.2-10 Comparison of Predicted and Observed Transect Average Dye Concentrations, Outfall 003 Survey, 2 May 2000

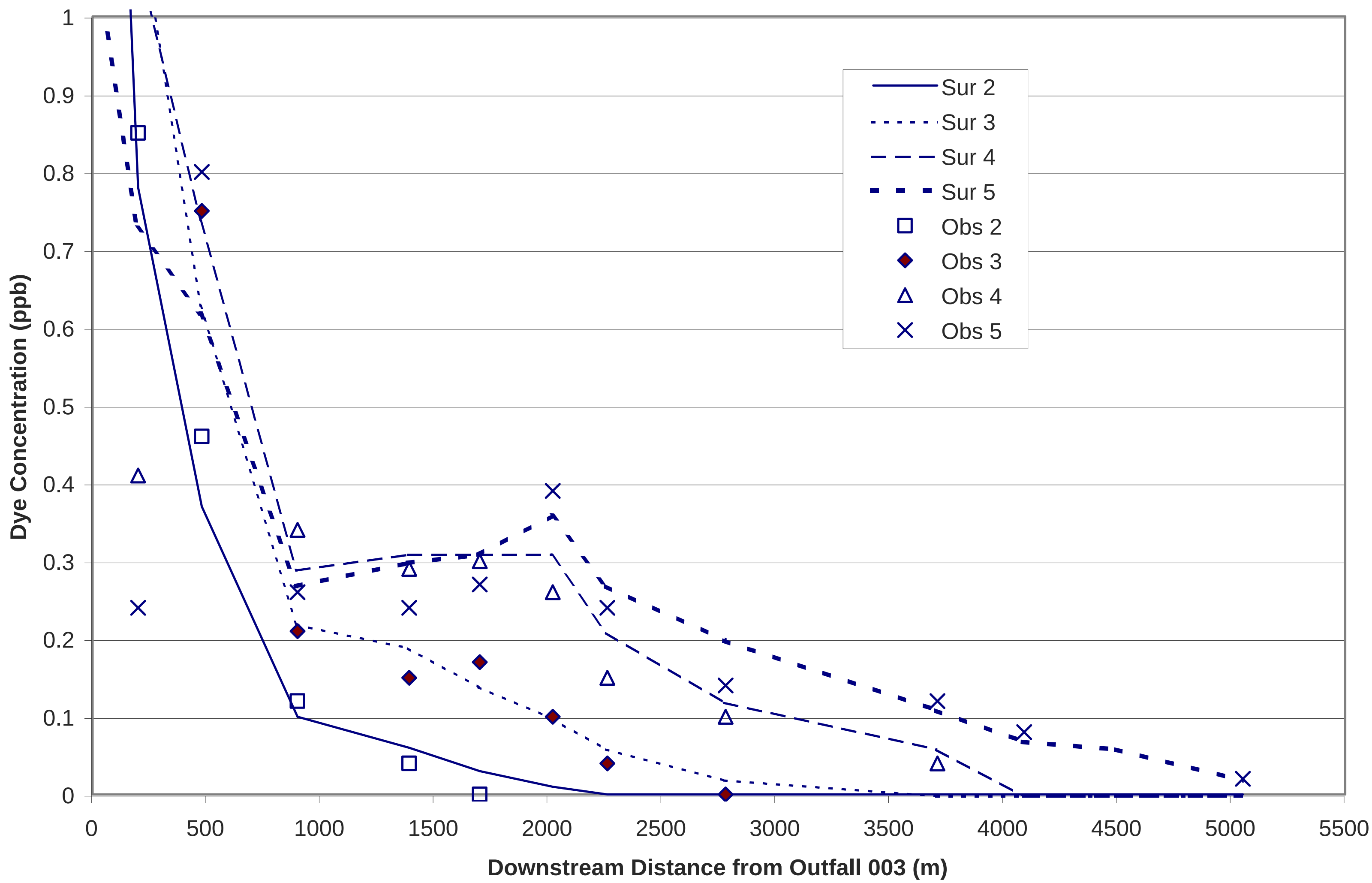
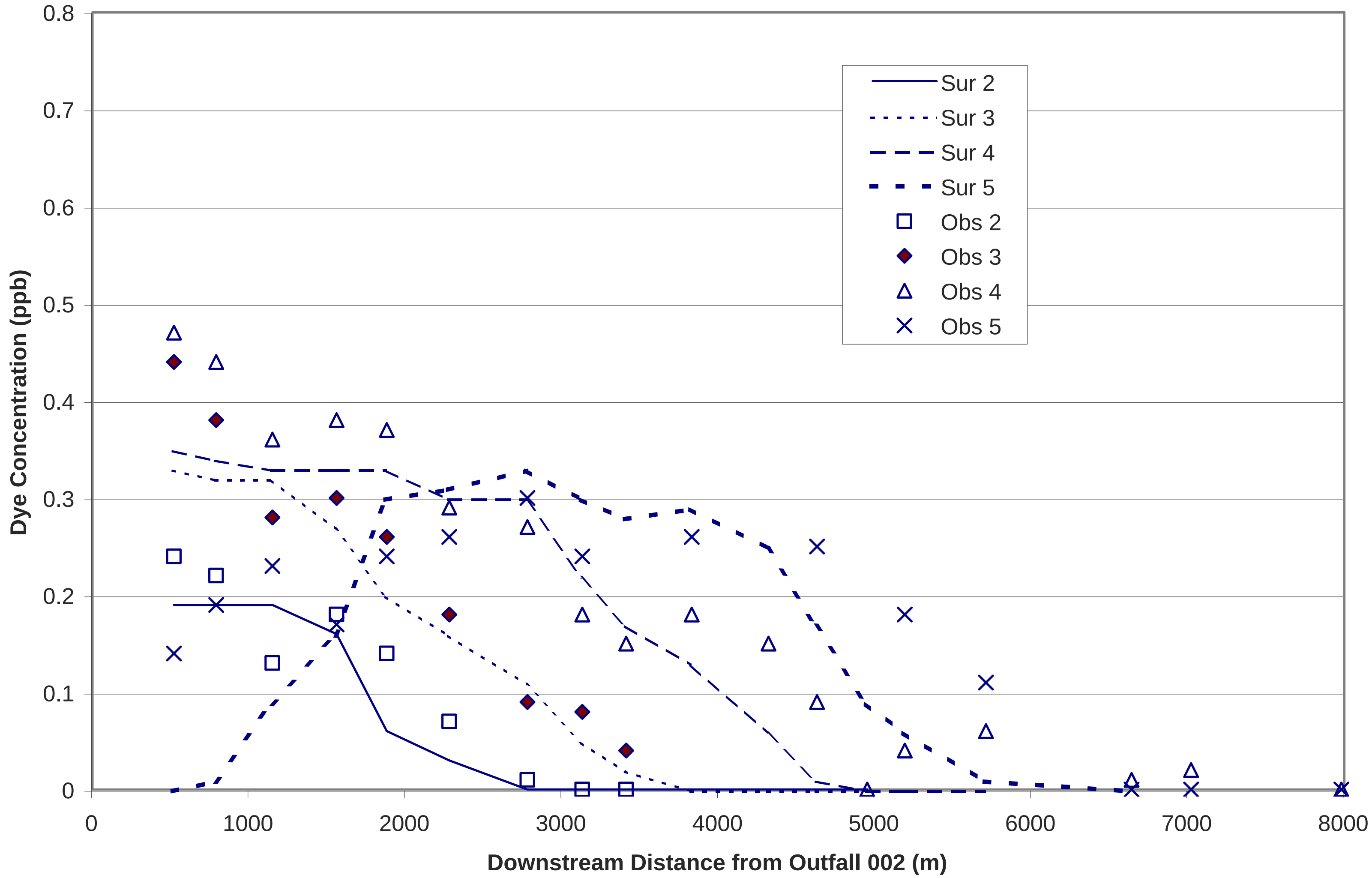
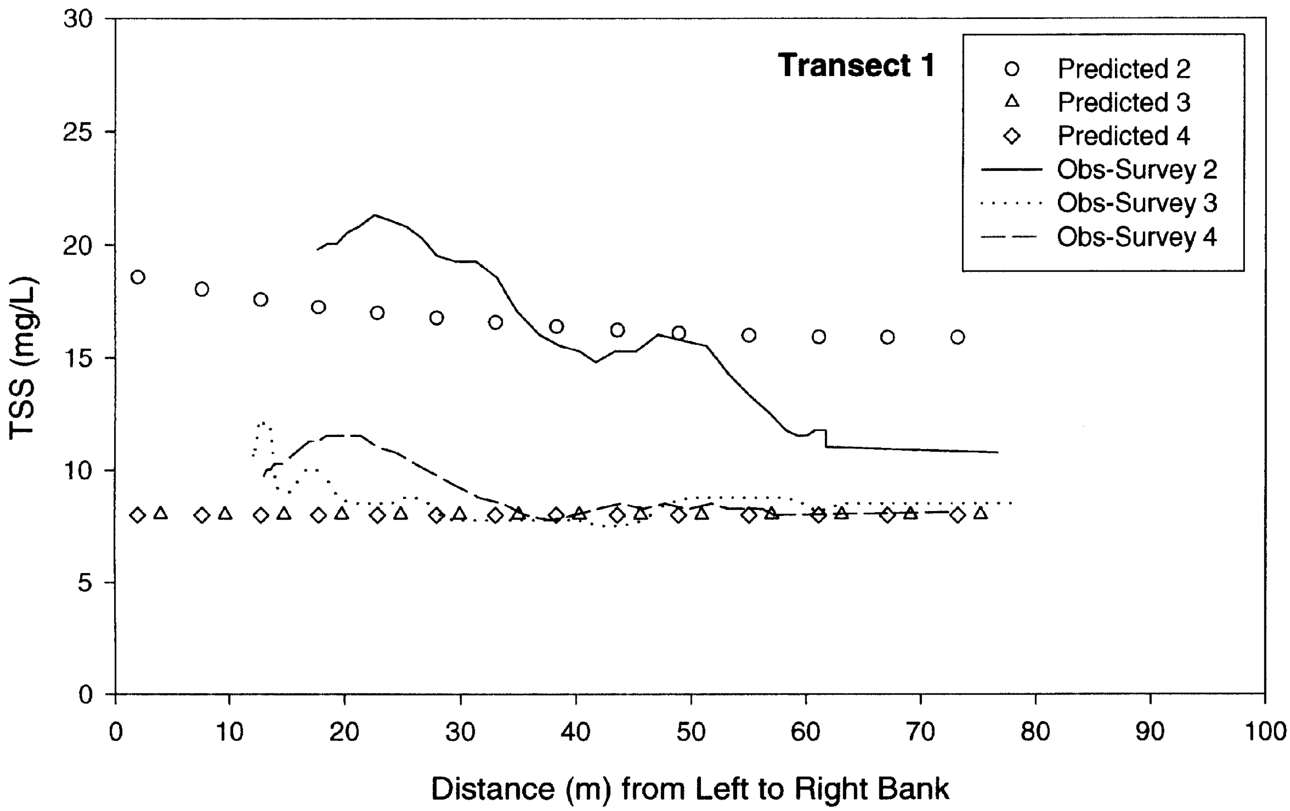


Figure B.2-11 Comparison of Predicted and Observed Transect Average Dye Concentrations, Outfall 002 Survey, 24 May 2000





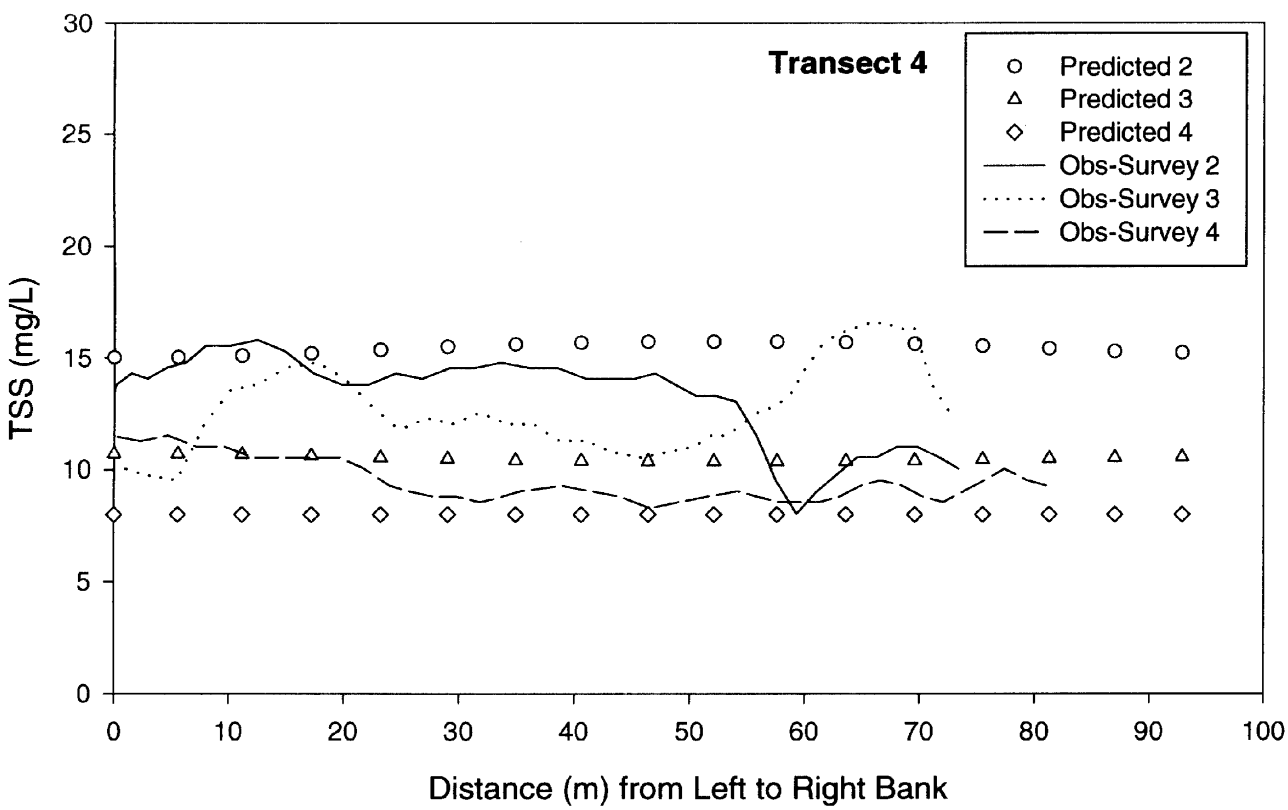
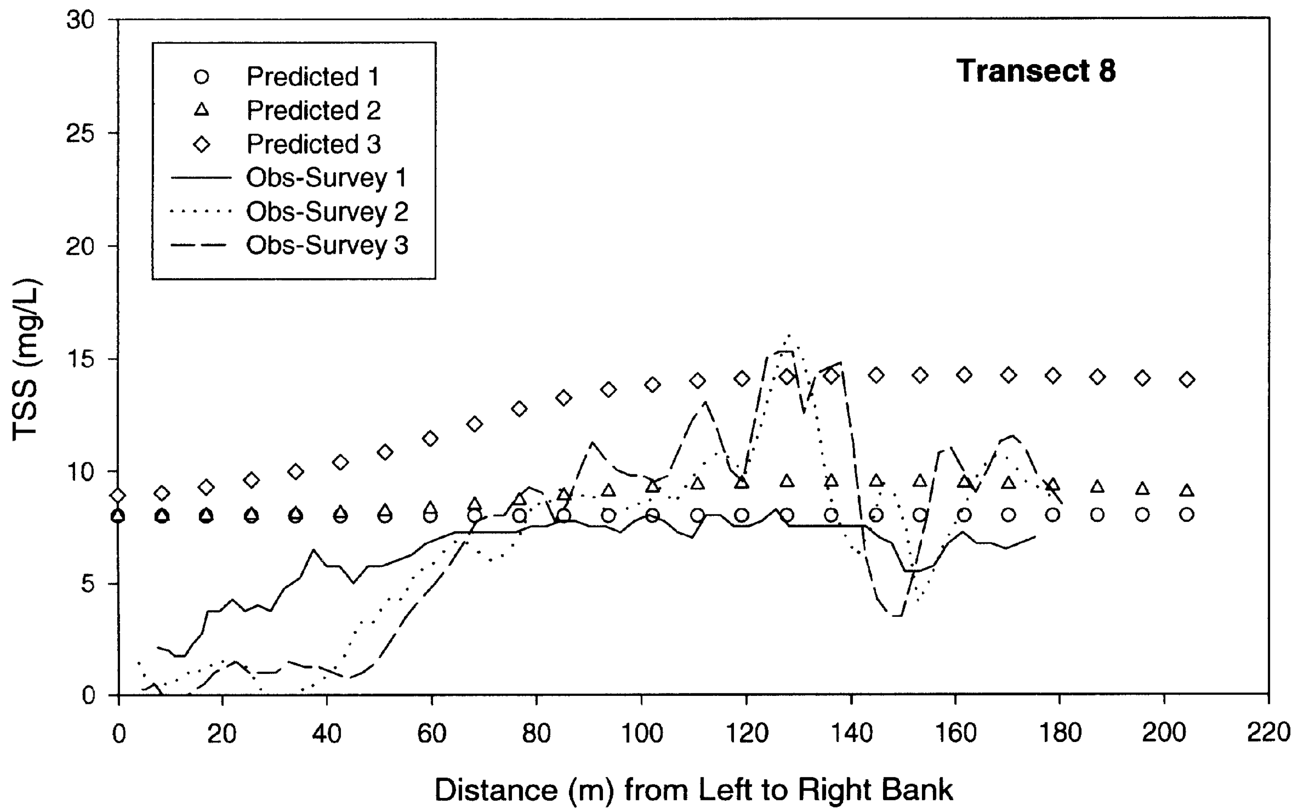


Figure B.2-12 Comparison of Observed and Model-Predicted TSS Concentrations at Transects 1 and 4, Outfall 002, 25 May 2000



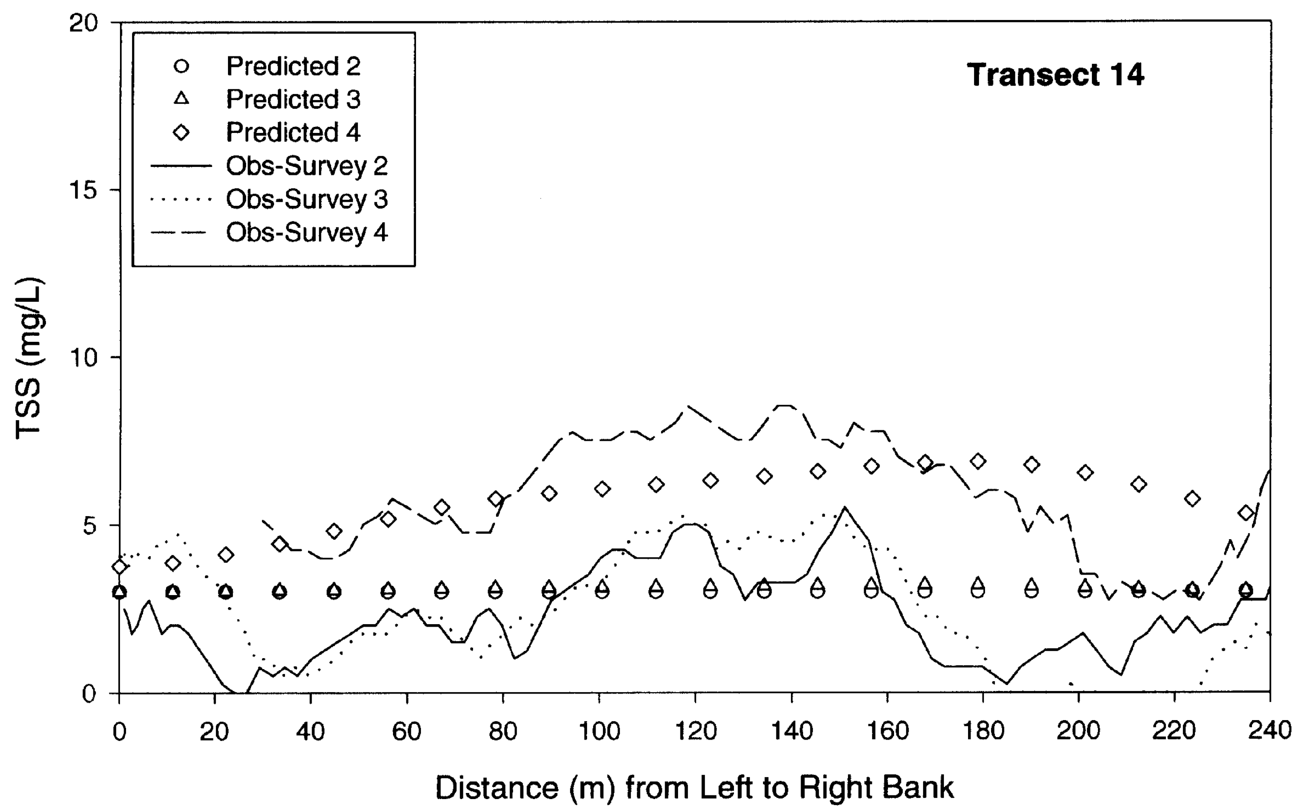
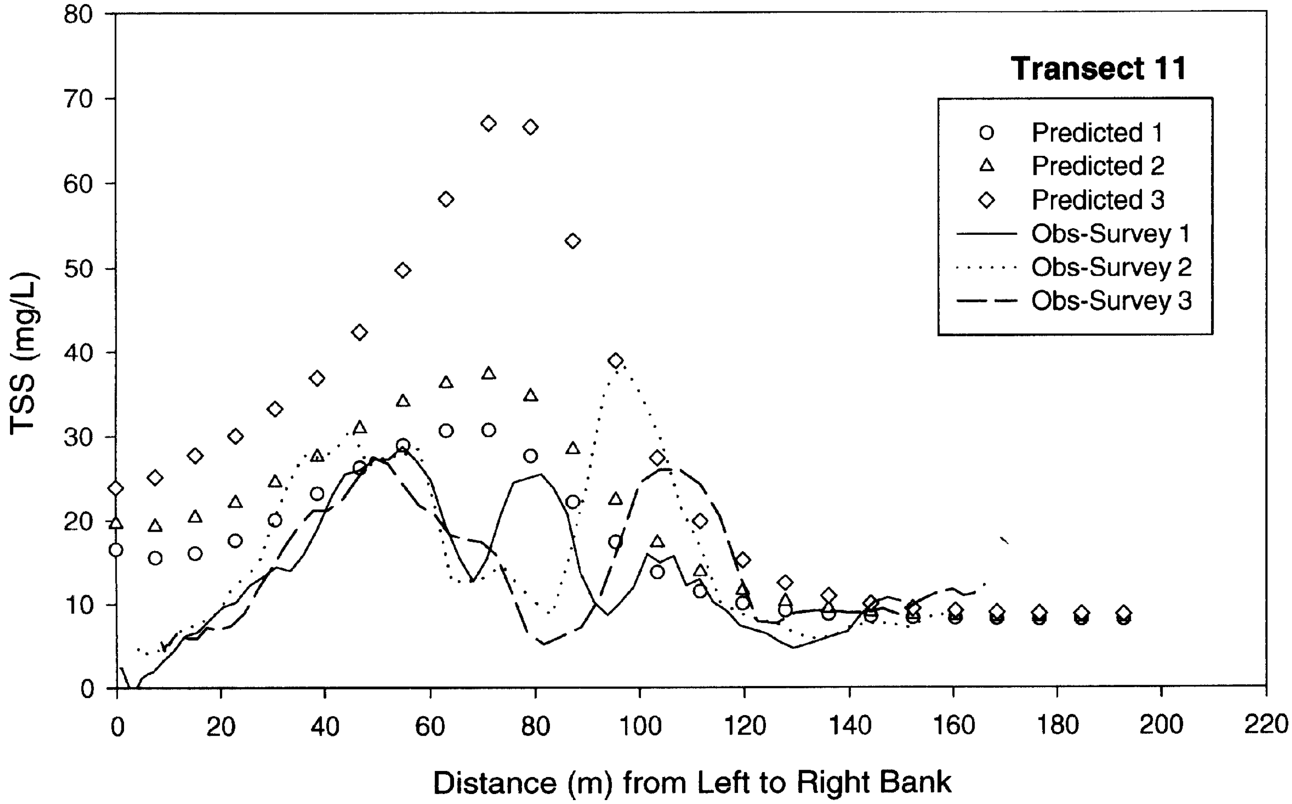


Figure B.2-13 Comparison of Observed and Model-Predicted TSS Concentrations at Transects 8 and 14, Outfall 002, 25 May 2000



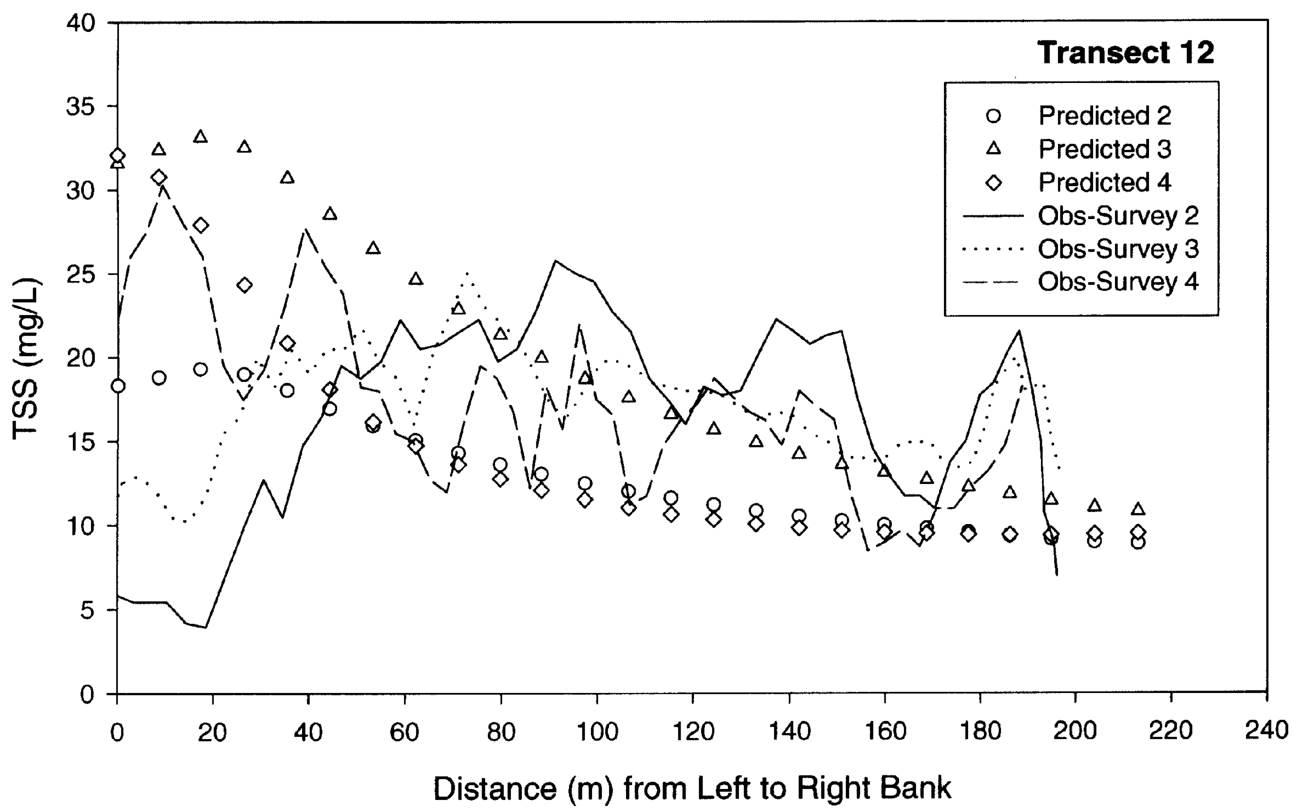
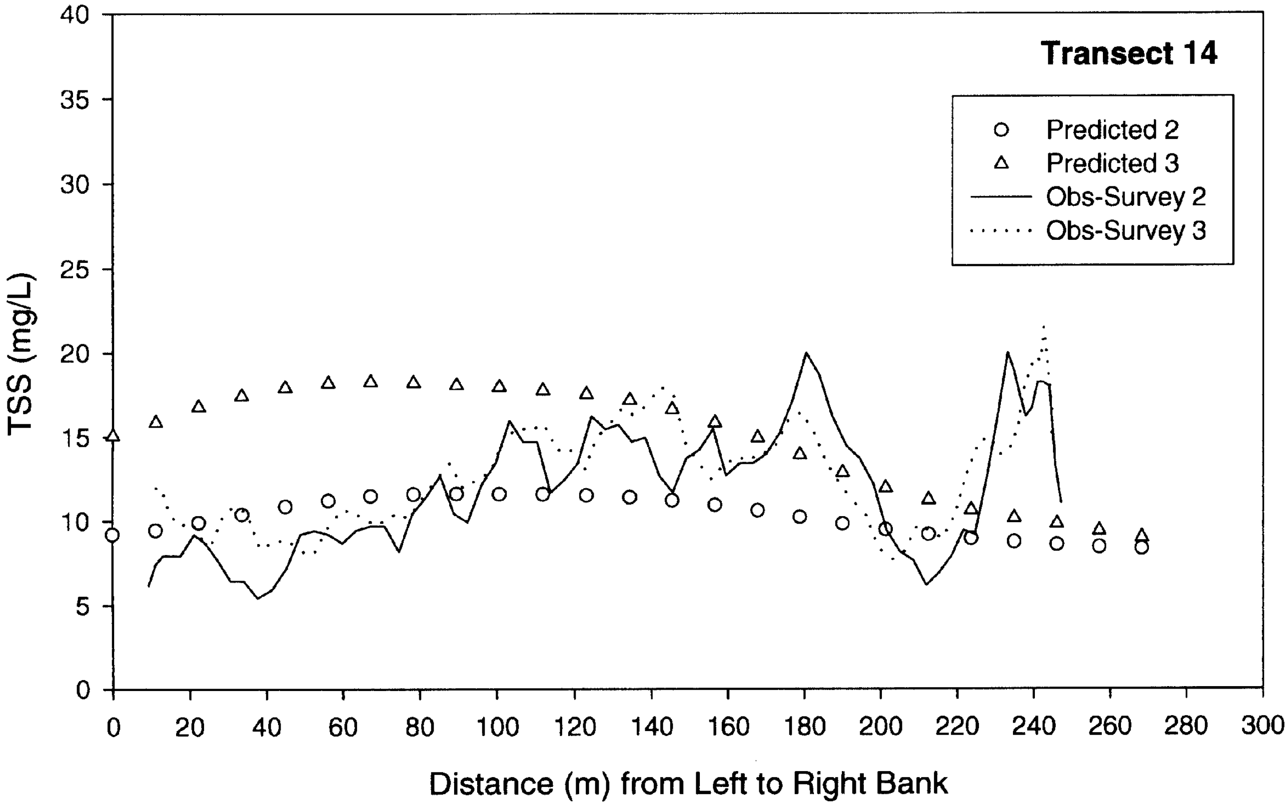


Figure B.2-14 Comparison of Observed and Model-Predicted TSS Concentrations at Transects 11 and 12, Outfall 003, 3 May 2000



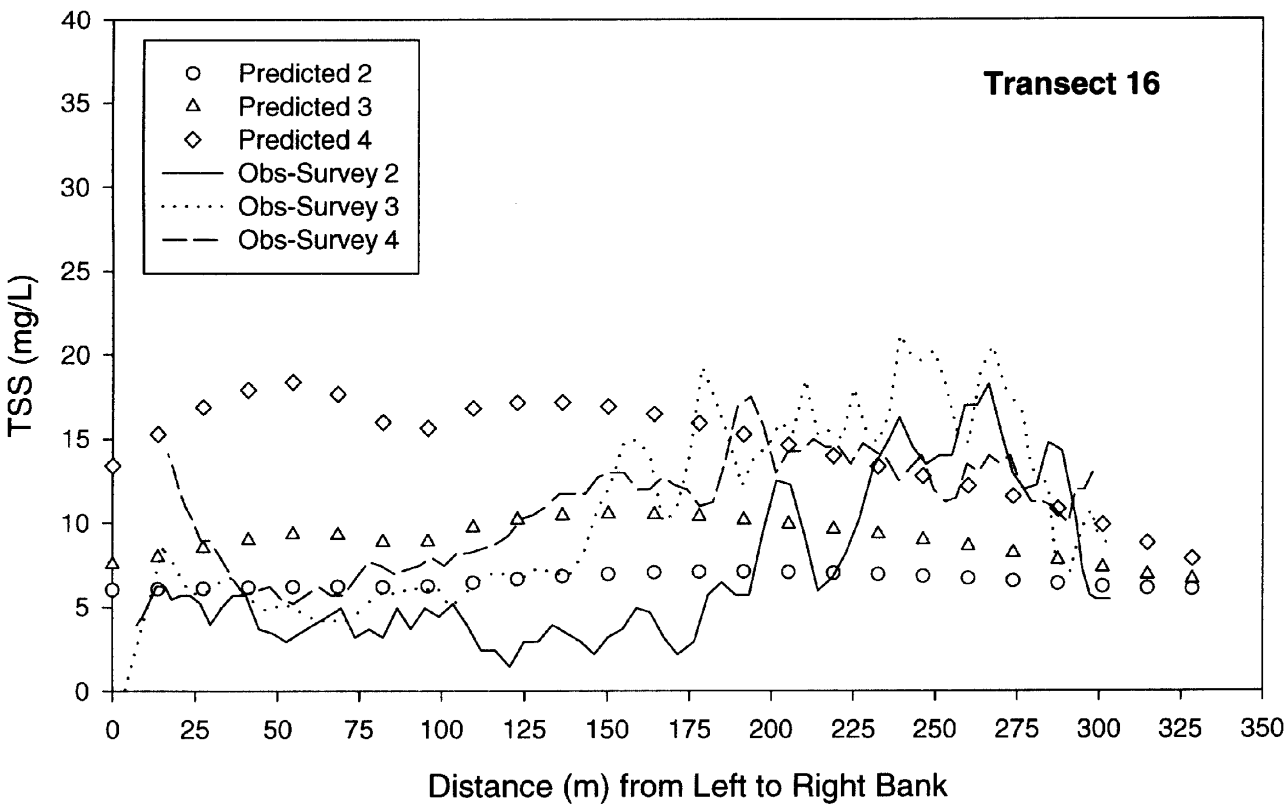


Figure B.2-15 Comparison of Observed and Model-Predicted TSS Concentrations at Transects 14 and 16, Outfall 003, 3 May 2000